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THESIS

OPTIMIZING POSITIONING OF NAVY WHOLESALE INVENTORY

by

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Naval Inventory Control Point (NAVICP) currently manages more than 210,000 line items to supply 957 customers worldwide. NAVICP positions these items within a distribution network of 22 Defense Depots operated by the Defense Logistics Agency (DLA). NAVICP plans to reduce supply system distribution cost by optimizing their use of this distribution network. This thesis develops a heuristic algorithm that optimally positions line items to serve historical requisitions by Naval units over an 18-month period. Repositioning minimizes distribution costs subject to constraints on customer wait time and depot capacities. This model suggests a distribution scheme for 32,521 unique wholesale items from 22 depots to 126 aggregated customer regions worldwide. The Navy can reduce distribution cost by better strategic positioning of Navy wholesale inventory within the existing distribution network. The Navy can also achieve savings by positioning stocks at just a few locations, rather than at many, and by positioning items together in aggregate product groups, a policy that is widely admired in logistics.

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OPTIMIZING POSITIONING OF NAVY WHOLESALE INVENTORY

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ABSTRACT

Naval Inventory Control Point (NAVICP) currently manages more than 210,000 line items to supply 957 customers worldwide. NAVICP positions these items within a distribution network of 22 Defense Depots operated by the Defense Logistics Agency (DLA). NAVICP plans to reduce supply system distribution cost by optimizing their use of this distribution network. This thesis develops a heuristic algorithm that optimally positions line items to serve historical requisitions by Naval units over an 18-month period. Repositioning minimizes distribution costs subject to constraints on customer wait time and depot capacities. This model suggests a distribution scheme for 32,521 unique wholesale items from 22 depots to 126 aggregated customer regions worldwide. The Navy can reduce distribution cost by better strategic positioning of Navy wholesale inventory within the existing distribution network. The Navy can also achieve savings by positioning stocks at just a few locations, rather than at many, and by positioning items together in aggregate product groups, a policy that is widely admired in logistics.

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LIST OF ACRONYMS

AMC	Air Mobility Command
APS	Advanced Planning and Scheduling
BRAC	Basic Realignment and Closure
CDR	Commander
DAAS	Defense Automatic Addressing System
DAASC	Defense Automatic Addressing System Center
DDC	Defense Distribution Center
DLA	Defense Logistics Agency
DoD	Department of Defense
DODMDS	Department of Defense Materiel Distribution System
FISC	Fleet and Industrial Supply Center
LCDR	Lieutenant Commander
NAVICP	Naval inventory Control point
NAVSUP	Naval Supply Systems Command
NIIN	National item identification Number
PC	Product Class
RIC	Routing Identification Code
SAILS	Strategic Analysis of Integrated Logistics Systems
SG	Supply Group
UIC	Unit Identification Code
UICP	Uniform Inventory Control Program

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EXECUTIVE SUMMARY

The Navy plans to optimize the use of its distribution network to reduce distribution cost. This thesis shows how the Navy can reduce distribution cost by better strategic positioning of wholesale inventory within this network. These savings can be achieved by increasing use of depots not collocated with Navy bases but with lower depot costs. This conclusion is the result of an extensive analysis of DLA's distribution network using a heuristic algorithm (implemented in java) that positions line items to achieve minimum distribution cost (including transportation and depot costs) subject to constraints on the maximum planned time to fill customer orders and depot capacities. This thesis derives a distribution scheme for 32,521 individual, unique wholesale items from 22 defense depots to 126 aggregated customer regions worldwide.

Naval Inventory Control Point (NAVICP) maintains worldwide control and visibility over Navy wholesale inventory. Presently, NAVICP manages more than 210,000 line items in wholesale inventory worth $1.05 billion and positions them within a distribution network of 21 Defense Logistics Agency depots in the continental US and one in Yokosuka, Japan. Although NAVICP manages its own wholesale inventory, which includes procuring, disposing, determining the stock level, and positioning within the DLA's distribution network, the DLA's Defense Distribution Center in New Cumberland, PA, is responsible for storing, handling, and executing physical distribution by filling requests of all the services. However, Defense Distribution Center does not decide where to locate Navy-managed material within its distribution system. Item managers in NAVICP determine where to position wholesale inventory within the DLA network by considering factors such as location of historical demand, special

requirements, or their own discretion. Currently, Navy wholesale inventory is stored in depots close to Navy bases.

This study uses a Demand History File provided by NAVICP. This file includes 934,877 line requisitions for 68,018 unique items from Navy wholesale inventory during the period of 1 October 1997, through 31 March 1999. The input data set is constructed from 845,433 different requisitions and 32,521 unique items (after deleting those items lacking weight and cube information in the demand history file). 957 Navy customers identified from the demand history file are aggregated to 126 demand regions by geographic proximity. Although DLA charges the Navy a standard fee for transporting an item regardless of where or how that item is shipped, transportation costs are considered discretionary while optimizing the flow of product through the distribution network.

Solutions produced using the various scenarios indicate that DLA depots currently have excess throughput capacity available, depot costs have a great impact on assigning wholesale inventory to depots, and deleting those depots that are not collocated with Navy bases and have high depot costs or those that are collocated with Navy bases and also are nearby other defense depots with lower depot costs barely affects the total distribution cost.

In addition, by individual item, or by item group, using just a few depots rather than many has scant effect on cost or service time. Locating items, or groups of like items, at just a few depots presents an attractive logistics strategy.

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I. INTRODUCTION

The mission of the Naval Inventory Control Point (NAVICP) is to provide program and supply support for the weapons systems that keep US Naval forces mission ready [NAVSUP, 2000]. Presently, NAVICP manages more than 210,000 line items as Navy wholesale inventory worth $1.05 billion [Evelhoch, 2000]. NAVICP positions this inventory within a distribution network of 21 Defense Logistics Agency (DLA) depots in the continental United States and one in Yokosuka, Japan.

Currently, Navy wholesale inventory is stocked in depots close to Navy bases. However, increased competition (resulting in higher consumer standards) and infrastructure changes have necessitated relocation of wholesale inventory for efficient and cost-effective distribution. Thus, NAVICP is seeking a strategic supply-chain planning tool that determines the optimal locations to stock Navy wholesale inventory [NAVICP, 1999].

The objective of this study is to determine the ideal positioning of Navy inventory. To satisfy this objective, the wholesale inventory positioning problem is formulated as a multi-commodity network-based linear programming model. The model's purpose is to minimize the associated costs subject to constraints on the maximum planned time to fill customer orders.

For given data and a network, this thesis can help answer many strategic questions, such as:

- Is it better to store wholesale inventory in a depot in close proximity to the customer, or at a more remote, modernized depot that would have a reduced processing time at lower cost?

- If DLA chooses to close a Defense Depot, where would NAVICP relocate the wholesale inventory now located there?

- If a ship's homeport were relocated, where would the necessary maintenance material be stored most efficiently? How would leaving the material at the former depot affect service and cost?

- NAVICP has recently discovered that due to a lack of indoor storage capacity, some expensive items labeled, "Do not get wet" are being stored outdoors. As a result, some material is damaged. How can NAVICP shift the related inventory to another depot where the indoor storage requirements are provided?

- If NAVICP were offered a Performance Based Logistic contract for superior service, what would it cost the Navy to deliver that level of service on its own? Performance Based Logistic includes total supply logistics support such as repair and replacement decision management, premium transportation, storage, and requisition processing.

A. OVERVIEW OF NAVY INVENTORY MANAGEMENT

This section provides basic information about the DLA distribution system, the Navy inventory system and Navy inventory management.

1. Defense Logistics Agency (DLA)

The Defense Logistics Agency is a logistics combat support agency whose primary mission is to provide supplies and services to US military forces worldwide. The origins of the DLA date back to World War II when America's huge military expansion required the rapid procurement of great amounts of munitions and supplies. After the war, a presidential commission recommended the centralization of common military logistics support management and the development of uniform financial management. Acting upon this recommendation, all military branches began to systematically buy, store and issue items through the DLA. [DLA Story, 2000]

Although each branch manages its own wholesale inventory, including procuring, disposing, determining the stock level, and positioning within the DLA's distribution

network, the DLA's Defense Distribution Center in New Cumberland, PA, is responsible for storing, handling, and executing the physical distribution requests of all the services. DLA manages only consumable items, supplies that are not repairable or are consumed in normal use. Defense Distribution Center does not decide where to locate Navy-managed material within its distribution system; NAVICP does.

DLA distribution system is a two-echelon system. Materials flow in large quantities from vendors to depots, and these depots ship in smaller order quantities to the customers. DLA operates 23 Defense depots worldwide with a total storage capacity of 527.8 million cubic feet (357.3 million cubic feet indoor capacity and 170.5 million cubic feet outdoor capacity) [DLA, 1999]. These depots are responsible for the receipt, storage and distribution of Navy inventory. A map of current defense depots is provided in Figure 1.1.

Today, DLA manages over four million consumable line items, and processes more than 30 million distribution actions annually [DLA, 2000]. Recently, DLA prescribed a plan for increased efficiency in which goods flow directly from vendors to customers [Kless, 2000].

The Basic Realignment and Closure (BRAC) process, developed in 1993, has had a profound impact on the way the agency approaches contract administration and supply distribution missions. Officials have merged, realigned, or closed several DLA primary-level field activities. Reducing the number of defense depots forces all service branches to diminish inventory size within the DLA distribution network. Instead of maintaining a huge inventory that lets NAVICP store requested items close to every demand point, NAVICP now has to position its inventory optimally to fulfill customer demand on time.

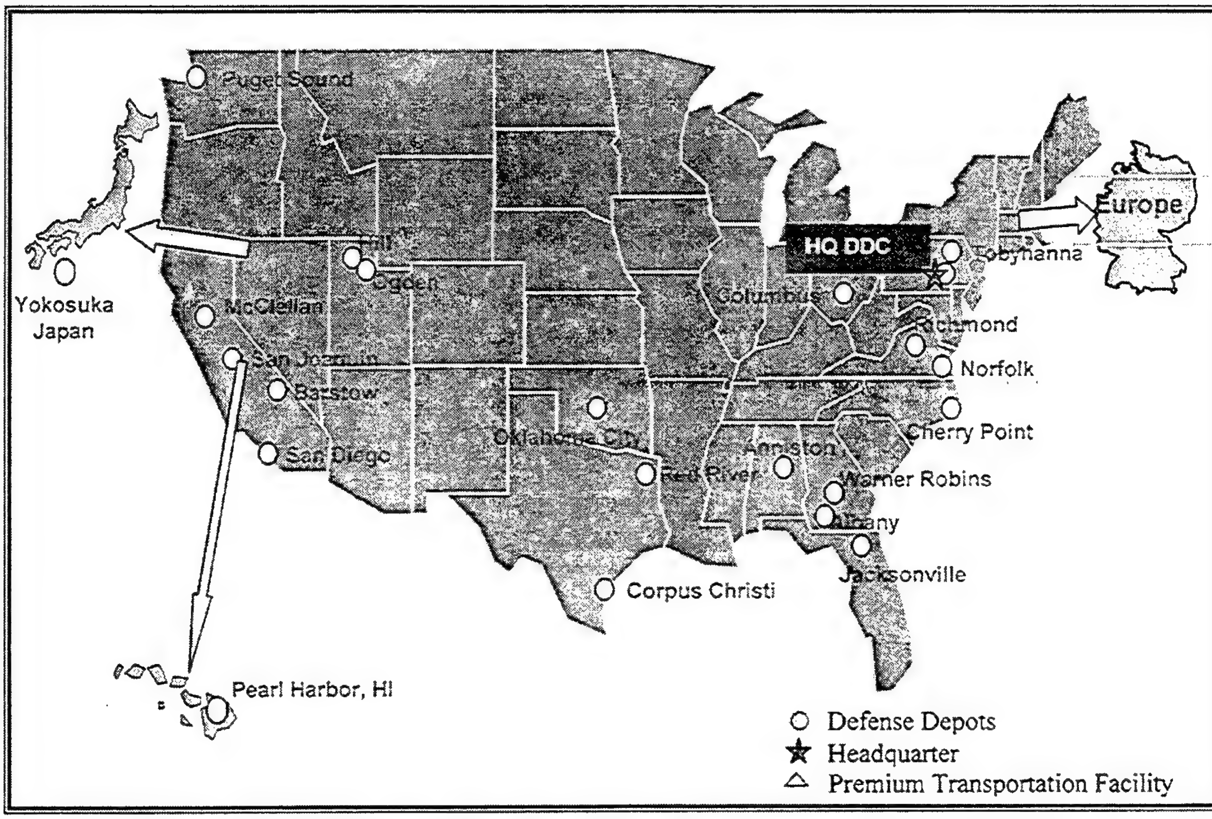

Figure 1.1: 23 Defense Depots and Premium Transportation Facility
[After Stanton, 2000]

Three of the defense depots are located outside the continental United States in Yokosuka, Japan; Pearl Harbor, Hawaii; and Germersheim, Germany. The defense depots in Susquehanna, PA, and San Joaquin, CA, are Primary Distribution Sites that are automated, modern, high-capacity and efficient depots.

2. Navy Inventory Control Point (NAVICP)

The mission of the NAVICP is to provide program and supply support for the weapons systems that keep US Naval forces mission ready. The tasks entailed by this objective are performed by a single command organization at the Naval Support Activities in Mechanicsburg and Philadelphia [NAVICP, 2000]. NAVICP is the sole controller of Navy wholesale inventory.

As a result of a need to reduce costs and infrastructure as well as to standardize inventory management, two former Inventory Control Points, the Aviation Supply Office

in Philadelphia, PA, and Ships Part Control Center in Mechanicsburg, PA, were consolidated as NAVICP in October 1995. This consolidation united all of the Navy's Program Support Inventory Control Point functions under a single command. The Philadelphia site primarily focuses on aviation and weapon system support, such as F/A-18 and V-22 aircraft, various engines, common avionics and support equipment. The Mechanicsburg site is responsible for the acquisition of hull, electrical, and mechanical components and repair parts for ships, submarines, and weapon systems.

3. Navy Inventory System

The Navy Inventory System's organization is similar in many ways to that of large companies that provide goods and services to customers in the private sector. The primary goal of both the Navy supply system and that of the private sector is to satisfy customers. The Navy inventory system is managed on a day-to-day basis by NAVICP. NAVICP is responsible for the requirements determination, advising material distribution and fulfillment of customer demands.

The items managed by NAVICP fall into three categories: Depot level repairable items, modification kits, and end items. A depot level repairable item is categorized as an item that is more economical to repair rather than procuring a new one. Each of these items is repaired at a specific repair depot at the direction of the NAVICP. These depots may be Navy activities, other DoD maintenance facilities, or private sector contractors.

A modification kit is a set of items composed of combinations of consumables, depot level repairable items and end items. Modification kits are used to alter the capability, function, or performance of an end item or component of an end item. Each

end item is a combination of end products, component parts, and materials that are intended for use on a stand-alone basis (i.e., a ship, tank, aircraft, etc.).

Every item within the Navy wholesale inventory has a unique National Stock Number-- a 13-digit code. The first four digits denote Supply Class, and the last nine digits give the National Item Identification Number. The supply class breaks down into two parts. The first two digits indicate the Supply Group that identifies the major item category (e.g., 10: weapons, 53: hardware & abrasive, etc.). The last two digits define the Product Class, the kind of item within that supply group (e.g., 1010: guns over 30 mm up to 75 mm, 5305: screws, etc.).

Each National stock number is managed in a group identified by a two-character alphanumeric cognizance symbol. Cognizance symbols are used to identify the method of wholesale funding and management type. For instance: 7G refers to ships electronic depot level repairable material managed by Navy Ships Parts Control Center in Mechanicsburg, PA; and 2R represents an aviation depot level repairable material managed by Naval Aviation Supply Office in Philadelphia, PA. The odd cognizance symbols represent Navy Working Capital Fund financing, and the even cognizance symbols represent appropriated funds. Figure 1.2 presents an example of a particular National stock number.

NATIONAL STOCK NUMBER

$$\underbrace{43}_{\text{SG}}\underbrace{20}_{\text{PC}} - \underbrace{01 - 068 - 4706}_{\text{NIIN}}$$

Figure 1.2: National Stock Number

National stock number of a rotary pump. Supply Group (SG) identifies the major item category (i.e., 43: Pumps and compressors). Product Class (PC) defines the kind of item within that supply group (i.e., 4320: Power and hand pumps). National Item Identification Number (NIIN) is a unique number for each item.

Navy wholesale inventory levels are determined by NAVICP. The item managers in NAVICP decide when to buy, how much to buy, when to repair, how much to repair, how much to hold on average, which units should be sent to disposal, which procurement action should be cancelled, etc. Item managers use the Uniform Inventory Control Program (UICP) to answer such questions. The UICP minimizes the annual variable cost equation composed of *ordering costs* + *holding costs* + *shortage costs. Ordering costs* include the total administrative expenses incurred while placing orders, the manufacturer's costs for the production or repair of items ordered, and the depots processing costs. *Holding costs* are those expenses arising from maintaining inventories on-site and the financial losses created when inventory becomes obsolete or otherwise unusable. *Shortage costs* result when incurring backorders.

This program uses five major files in requirement determination: the Master Data File contains all NAVICP managed, stocked items and Hardware Systems Command

items data. The Repairable Items Management File assists in the management of depot level repairable items. The Planned Program Requirements File contains an entry for each stock number that has one or more planned requirements or reservations established. The Due-in/Due-out File contains an item entry for any significant supply event that impacts the inventory system's assets. The Inventory History File is a historical record for each item.

The UICP does not necessarily minimize distribution cost. The program positions the wholesale material depending on the historical percentage of demand (i.e., if 20% of worldwide demand has been filled by San Diego, CA, then UICP recommends the positioning of 20% of the wholesale material there). However, item managers can choose another place if there are overriding factors such as a lack of proper storage capacity, the proximity of repair activities to storage depots, and the shipment of all goods to one location instead of multiple locations if this action reduces the transportation cost.

UICP does not consider the following: (1) depot-to-depot differences in receipt and issue costs; (2) transportation costs from vendors to depots and from depots to customers; and (3) logistics response time while positioning items.

A DLA depot may not be used as a distribution point for Navy material if the depot is not collocated with one of the Navy Fleet and Industrial Supply Centers (FISC), except Cherry Point, NC, and Ingleside, TX. UICP also positions the depot level repairable items returned from a repair facility at the closest depot to that repair facility to minimize the transportation cost, and does not consider the demand projection for those repairable items. [Reich, 1999]

4. Customer Wait Time

Customer Wait Time represents the total elapsed time between issuance of a customer order and satisfaction of that order. Regardless of commodity or source, customer wait time includes all customer orders, immediate orders or backorders. Logistics Response Time is the time from submitting a request by a customer until the customer electronically acknowledges the receipt at the Defense Automatic Addressing System (DAAS). In other words, customer wait time includes both wholesale and retail transactions where logistics response time includes wholesale transactions only. The DoD measures logistics response time with the Logistics Metrics Analysis Reporting System, Defense Automatic Addressing System Center, and Requisition Response Time Management Information System [Klaczak, 2000a].

In 1997, the Navy stopped using Requisition Response Time Management Information System for data collection and began using Logistics Metrics Analysis Reporting System. The latter system has the capability to track goods as they flow through various nodes of the logistics pipeline, and reports the associated response times. Defense Automatic Addressing System Center designs, develops and implements logistics solutions that improve customers' requisition processing and logistics management process worldwide. All services provide data to this system and monitor logistics response time performance in the Requisition Response Time Management Information System.

The Navy focuses on five main components in logistics response time: (1) Requisition Submission Time, the elapsed time from the date on the requisition is received at DAAS; (2) Initial Source Processing Time, the elapsed time from

transmission of requisition by DAAS to receipt by DAAS of supply action from the NAVICP; (3) Depot Processing Time, the elapsed time from release of material order by DAAS to the shipment date shown in a shipment status transaction received by DAAS; (4) Transportation Time, the elapsed time from shipment of material from depot until the date the local retail site receives the material; and (5) Receipt Take Up Time, the elapsed time that passes between receipt of goods by a local retail site and the logging of its status as site inventory or issue to the end customer. Figure 1.3 shows how logistics response time is comprised of various components.

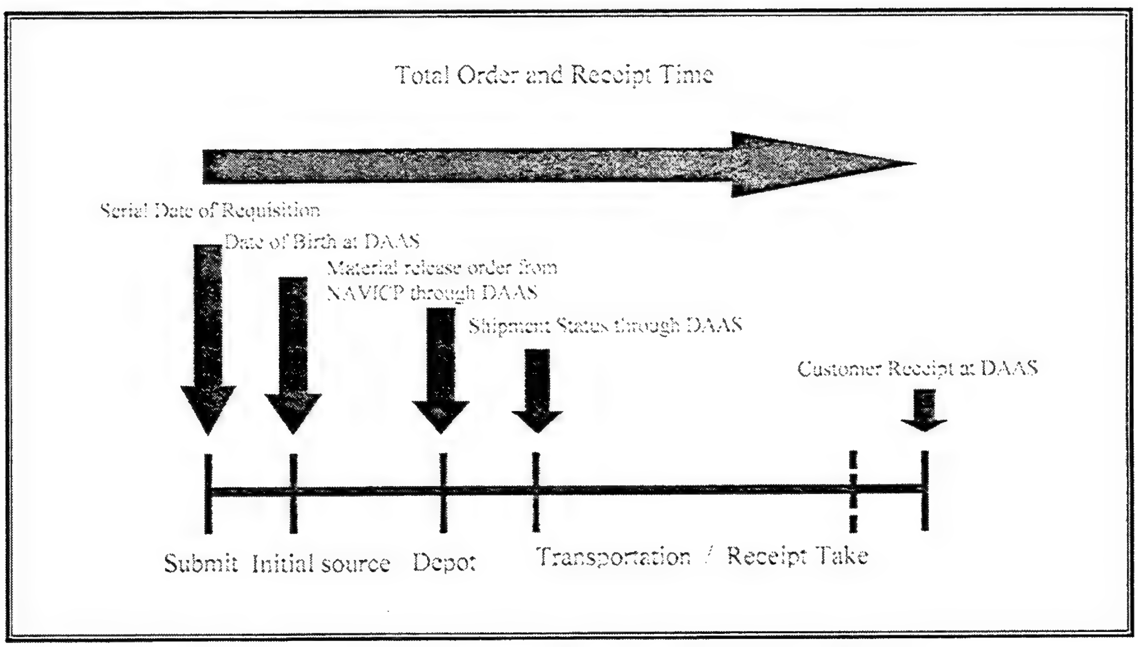

Figure 1.3: Components of Logistics Response Time

NAVICP focuses on five time steps recorded at Defense Automatic Addressing System during logistics response time: (1) Submission of a request at Defense Automatic Addressing System, (2) Defining the source depot for that requisition, (3) NAVICP's material release order to the depot for the request, (4) Shipping the material from the depot, and (5) the customer receives the material.

The National Performance Review goal mandated by Vice President Gore was a 50% reduction in logistic response time by February 2000. The Navy reduced total order

to receipt time by 50% from February 1997 to February 2000, e.g. from 46 days to 23 days (Figure 1.4). [Klaczak, 2000b]

In order to increase productivity by achieving further reductions, NAVICP and the Naval Supply Systems Command (NAVSUP) collaborated to form Process Improvement Teams in late 1998 to analyze the steps in each component of logistics response time.

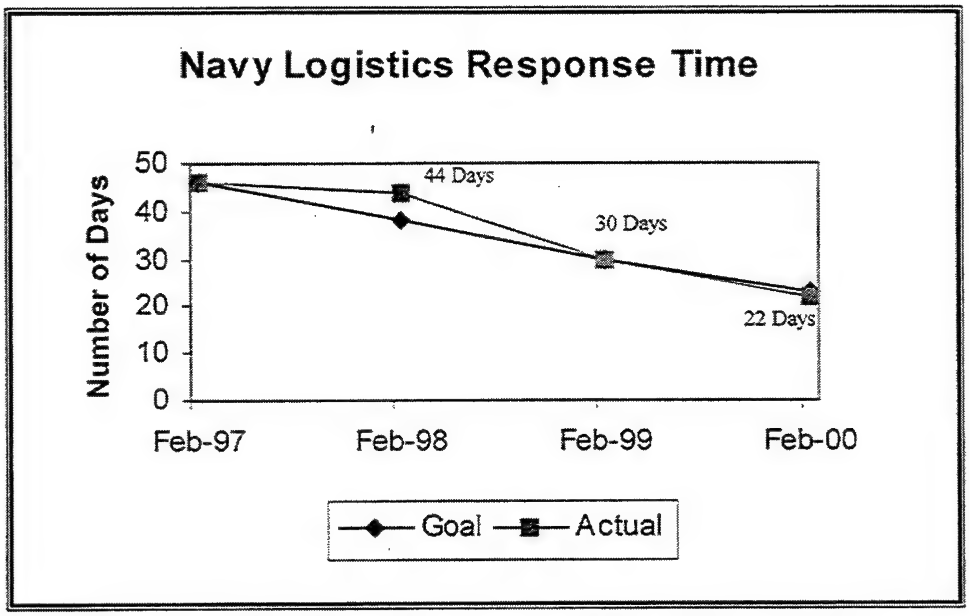

Figure 1.4: Navy Logistics Response Time Reducing Plan
Up to February 1997, the Navy had a logistics response time at over 46 days. The Navy reduced this by 50% to 23 days in three years.

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II. RELATED STUDIES

In many real-world situations where companies sell large quantities of products, it is necessary to store inventory in warehouses in order to meet market demands. Successful logistics planning has become paramount for organizational success. The Council of Logistics Management defines logistics as, "... the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from the point of consumption for the purpose of confirming to customer requirements" [Handfield and Ernest, 1999].

Ballou [1992] decomposes logistics planning into three stages: operational, tactical and strategic plans. The major difference between them is the time horizon for the planning. *Operational planning* is essentially short-term planning, and emphasizes immediate results. *Tactical planning* typically spans a time frame of less than one year. *Strategic planning* entails planning over the long term, typically for more than one year.

The creation of a distribution network is an aspect of strategic planning because distribution network designs involve the number, size and location of distribution centers, the choice of transportation types and the location of inventories. Currently, NAVICP is working on a project known as Advanced Planning and Scheduling (APS). A primary component of this project focuses on strategic positioning and transportation. The objectives are to determine if (1) an APS strategic positioning tool can meet NAVICP requirements to reduce cost and customer wait time, and if (2) an APS tool has the potential to improve the transportation planning and operating process to reduce customer wait time. Figure 2.1 identifies the NAVICP APS projects [NAVICP, EDS, 2000].

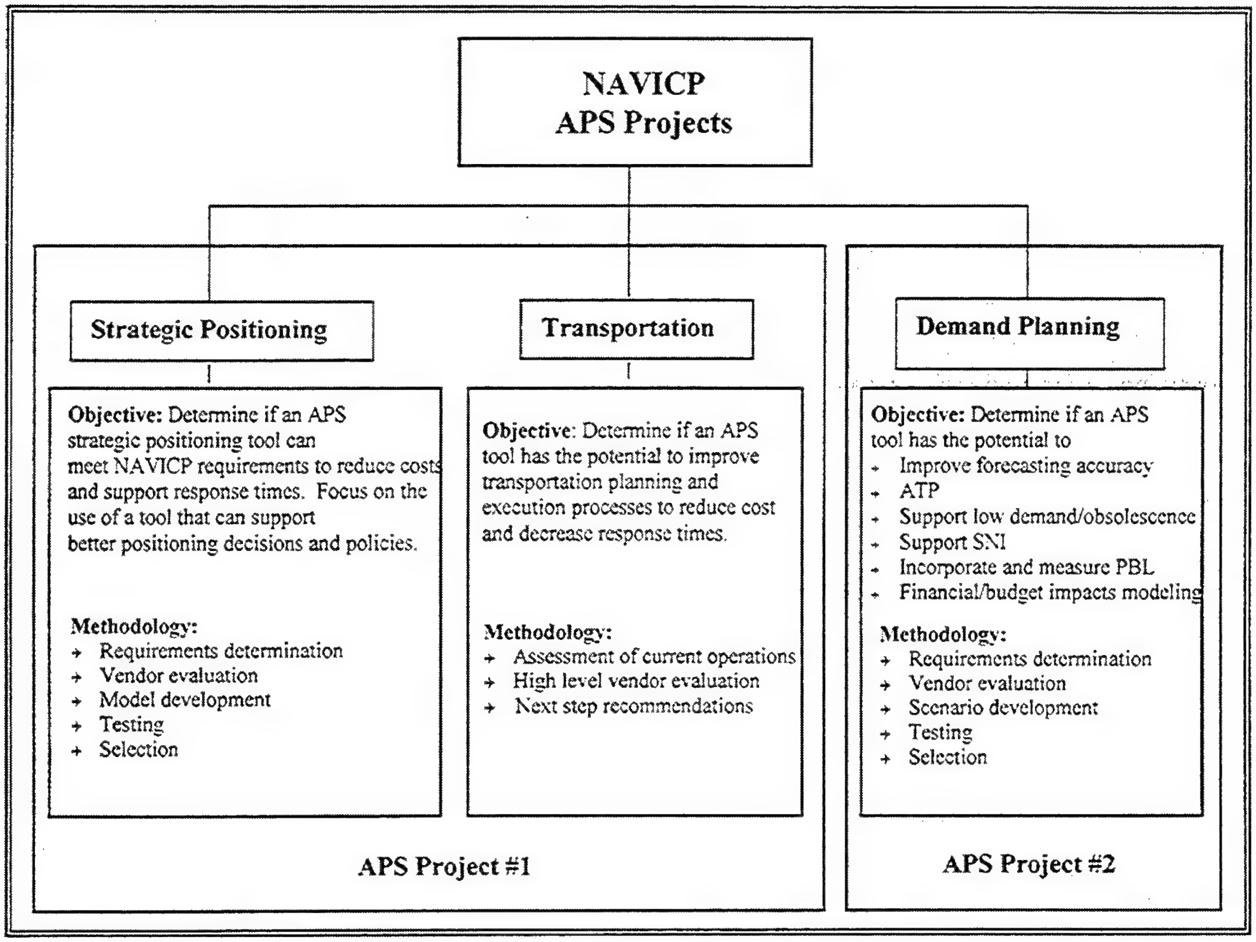

Figure 2.1: NAVICP Advanced Planning and Scheduling Projects
[From NAVICP, EDS, 2000]

One part of this project focuses on (1) strategic positioning to meet NAVICP requirements to reduce cost and customer wait time, and (2) transportation to improve transportation planning and operating process to reduce customer wait time; the other part focuses on demand planning to improve forecasting accuracy.

This thesis examines the Navy's wholesale inventory distribution network, which operates within the DLA's distribution network, and analyzes strategic positioning of the Navy inventory with respect to meeting customer demands. For such problems, Holmberg, Ronnqvist and Yuan [1999] advise using multi-commodity network models due to the ability of these models to minimize cost.

A. PREVIOUS STUDIES OF DISTRIBUTION NETWORKS

1. DLA Distribution Network Studies

After the Vietnam War, a joint service commission prepared the Department of Defense Materiel Distribution System (DODMDS) study to reduce DoD operating costs by examining the DoD distribution system. This study analyzed the entire distribution system, including the maintenance and storage facilities then operated by the Army, Navy, Marines, Air Force and DLA within the continental US. This study covers all inventory managed by those services with the exception of: bulk petroleum; perishable subsistence; ammunition; chemical, biological and radiological items; industrial plant equipment; and some major end items [DODMDS, 1978].

This study provides an optimal distribution network solution for the DoD, and states that $100 million (1976) annually in savings may be possible by closing nine depots and positioning certain material categories closer to customers. The DODMDS study includes a mixed integer linear programming model to minimize operating cost and a simulation model to evaluate system and depot capacities. The DODMDS study aggregates things as follows: 15 depot locations are grouped from 34 depots, 142 procurement sources are grouped from 19,000 vendors, 205 demand regions are aggregated from 50,000 domestic customers and 27 product groups are formed from 3.5 million unique items.

Holmes [1994] analyzes the DLA distribution network and proposes depot closure candidates in order to support a 1995 budget reduction. In 1994, the DLA operated 28 depots and supplied over 45,000 customers with an excess of three million products procured from over 10,000 suppliers. Holmes investigates 29 aggregate products, 113

aggregate customers, and uses a commercial network design product known as Strategic Analysis of Integrated Logistics Systems (SAILS) [Insight Inc., 1993]. The Holmes Study uses many of the 1978 Department of Defense Materiel Distribution Systems' techniques to derive product, customer, supplier and transportation mode aggregation schemes.

However, Holmes observes that Hobbs and Lanagan [1994] have found demand variability for DLA on three levels: across all commodities, between depots, and between demand regions, whereas annualized demands are assumed stable in the DODMDS study. A thorough analysis by Holmes indicates that (1) DLA depots are not being filled to capacity, and (2) alternate solutions are possible under the current DLA distribution network. Finally, Holmes concludes that, "...with recent improvements in transportation services and delivery times, no significant improvement in customer service is obtainable by ensuring depots are located 'close' to or even collocated with all customers" [Holmes, 1994].

Reich [1999] analyzes the DLA distribution network and proposes utilizing distribution points which are not collocated with Navy activities. Reich derives a simplified six-mode transportation scheme and aggregated customers for 57 depot level repairable items by using techniques suggested by the DODMDS and Holmes studies. However, Reich uses individual items in his model rather than aggregated items as in the DODMDS and Holmes studies.

The results of the Reich study imply that, (a) a privately owned Premium Transportation Facility is often the low-cost solution; (b) low weight items are not good candidates to store in a premium transportation facility; and (c) deleting DLA depots

from the network barely affects the operating cost, while the associated customer wait time decreases significantly. Finally, Reich suggests that NAVICP should reposition more items into premium transportation facilities.

2. Civilian Distribution Network Studies

A number of studies have been conducted on distribution network design, including, Geoffrion [1976a]; Geoffrion [1976b]; Magae, Capacino, and Rosenfield [1985]; Ballou [1992]; Erkut and Bozkaya [1999]; Morales, Van Nunen, and Romijin [1999], Tragantalerngsak, Holt, and Ronnqvist [2000]; Hinojosa, Puerto, and Fernandez [2000]. These studies suggest various models to reduce cost.

In many instances, facilities distribute a large number of different products to hundreds of individual customers, and therefore it may not be realistic to model each individual customer. Data aggregation in such location problems reduces the problem size to a manageable one. Zipkin [1977] defines an aggregate problem as partitioning the variables or constraints in the original problem, and replacing each group with a single variable or constraint.

Aggregate problems may admit some errors in solution details. Bender [1985] highlights the critical to need to determine the correct level of data aggregation in these problems. He points out that as the data becomes more aggregated, potential errors in analysis increase, but analysis is simpler and cheaper.

Although recent improvements in computer technology allow much more complex transaction files, data aggregation is still necessary. Dantzig's seminal discussion of the role of aggregation in modeling is still enlightening. He recognizes that, "...any model can represent only approximately the real situation, and the best that one

can do is to accept the model at a certain point of refinement as sufficiently representative to begin calculations" [Dantzig, 1948].

Despite a considerable amount of research on distribution network design in recent years, little has been written on data aggregation and the effects of using such techniques.

a. Product Aggregation

Product aggregation is universally applied. Usually, a considerable number of products flow in a product distribution network. Defining each of these products individually is impractical for any distribution network model. Thus, some product aggregation is useful. Bender [1985] identifies four key factors to consider when aggregating products:

- *Marketing Factors*: Identify the main products as those that account for the bulk of volume shipped. Treat similar products separately that have different sale ratios in different markets.
- *Logistics Factors*: Aggregate products with similar transportation and handling rates, and storage characteristics.
- *Production Factors*: Aggregate all products that have similar unit production costs or are made together at the same plant, in the same ratios. Some special products may be identified separately.
- *Organizational Factors*: Display organizational units separately for similar products if they are from different units.

b. Customer Aggregation

A number of approaches have been used in previous studies to aggregate customers. Holmes [1994] defines some methods to group customers by geographic proximity, type of customer, type of export, or customer service requirements.

According to House and Jamie [1992], grouping customers by geographic proximity is the most practical approach. In this method, some georeferent such as three-digit zip code is used as a starting point. The three-digit zip codes closest to each other are joined to form a cluster. Then, these clusters are grouped roughly according to population density. This grouping may produce large clusters in the less densely populated regions. The dominant population point in the cluster is the cluster center, and is identified to represent the point to which all volume in the cluster is assumed to flow. This process is repeated until the desired number of clusters is reached.

Transportation costs are based on the distance measured between product source and the cluster center, rather than on the calculation of the true cost from product source to an actual customer location. The aggregation literature in location analysis has identified three different sources of error [Erkut and Bozkaya, 1999]:

- *Source A Transportation Cost Errors*: Cost errors occur by measuring the distance to the product source from the cluster center instead of from the actual demand location while calculating transportation cost. Figure 2.2 displays four demand points that have been aggregated into one. All distances between a product source (anywhere on the plane), and these four demand points will be approximated by the distance between the product source and the cluster center. This will result in some measurement error.

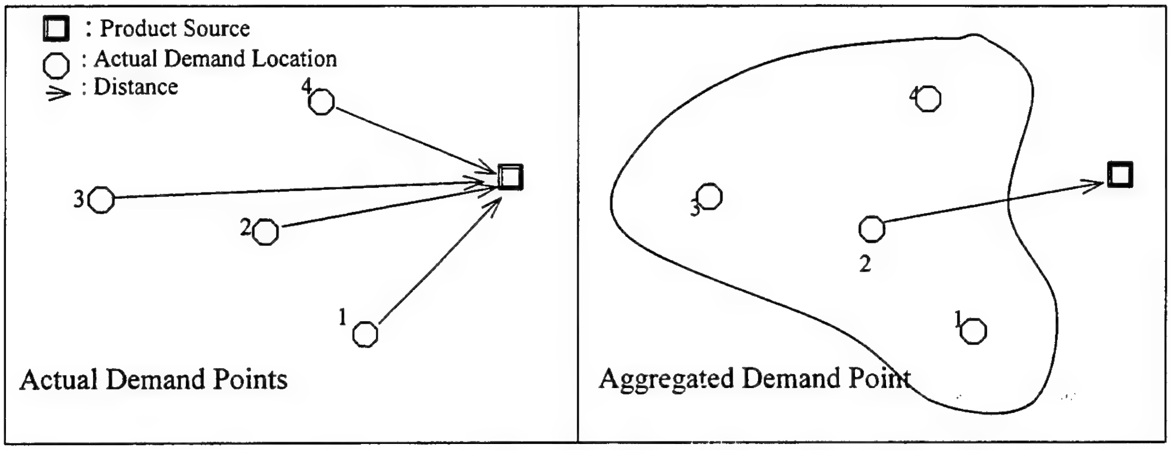

Figure 2.2: Source A Transportation Cost Error from Aggregating Customers
After aggregating four demand locations, the distance from demand locations to the product source is the same as between the product source and demand location-2, the cluster center.

- *Source B Distance Errors*: This type of error is a special type of source A transportation cost error. If the product source is located at the cluster center, then the distance from the product source to a demand location in that cluster will be zero. This measurement underestimates the true transportation cost. In the literature, source A transportation error and source B distance error are also known as cost errors.

- *Source C Sourcing Errors*: Optimality errors are created when distances from cluster centers to product sources are used to assign demand to the nearest center. In this situation, some demand may be assigned to the wrong source. Suppose the four demand points in Figure 2.3 are aggregated in the same way as in Figure 2.2. Since the cluster center is closer to Facility 1, the aggregated model would allocate four demand points to Facility 1. However, some of the demand points are actually closer to Facility 2, and they would logically choose to be served by this closer facility.

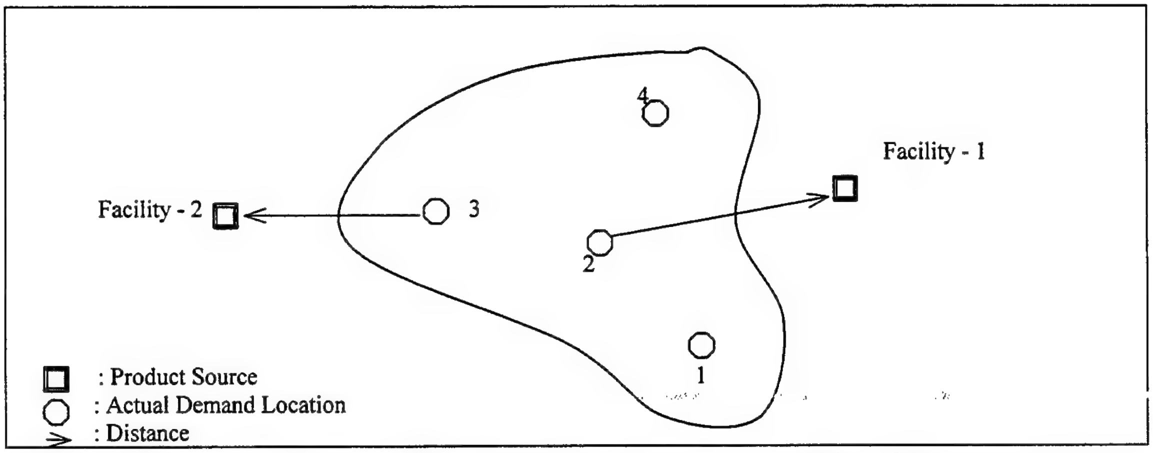

Figure 2.3: Source C Sourcing Error from Aggregating Customers

Although demand point-3 is closer to Facility-2 than to Facility-1, all demand points in the cluster are assigned to Facility-1, because the cluster center (demand point-2) is closer to Facility-1.

Current and Shilling [1987] have studied a real-world distribution network problem containing 681 demand points. These points are respectively aggregated to 30 and 70 nodes. The location problem is solved with five, seven, and nine product source points, and four different demand data sets. They discover that:

- There is a positive correlation between the number of product sources and both sourcing and cost errors. The errors increase monotonically with the number of sources.
- There is a negative correlation between the number of demand regions and both sourcing and cost errors. The errors decrease when the number of demand regions increases.

Ballou [1994] examines the cost errors occurring in an aggregated distribution system. He determines the effects of the number of source points, clusters, and the size of the clusters on the cost errors. His study analyzes a distribution network composed of source points from 1 to 100, demand clusters from 50 to 900, and shipment sizes from 500 pounds to a full truckload. He reports the following:

- The common practice of using 100 to 200 demand clusters is not applicable to all problems. 200 demand clusters appears appropriate

for a network with up to 25 product source points, but the number of demand clusters should be increased when above 25 points.

- Controlling the cluster size reduces cost errors.
- Cost errors do not exceed 1.5 percent when considering basic guidelines for cluster formation.
- Cost errors decrease as the number of clusters increase, or as the number of source points decrease.
- Cost errors increase with the increased number of facilities relative to the number of clusters.
- Shipment size and the associated transportation rates affect the magnitude of cost errors.
- Aggregating customers by proximity is a reasonable approach to form clusters and reduces cost errors.

For distribution networks with 25 source points (DLA's size), Ballou suggests more than 200 demand clusters. However, this recommendation seems inapplicable to the current study, because the top 100 demand clusters account for approximately 90 percent of the items processed. Also, we find that transportation rates do not change significantly for depot-demand region pairs when the first three zip code digits of each pair match. For these reasons, we speculate that no significant increase in transportation cost accuracy can be gained by increasing the number of demand clusters much above 100.

III. DATA SET

This section contains information on test data and describes the construction of the major components of the model.

A. HISTORICAL TRANSACTION FILE

This study uses a Demand History File provided by NAVICP. This file includes 934,877 line requisitions for 68,018 unique items from Navy wholesale inventory during the period of 1 October 1997, through 31 March 1999. The data set is constructed from 845,433 different requisitions and 32,521 unique items (after deleting those items lacking weight and cube information in the demand file).

B. CUSTOMERS

Every Navy requisition contains a Unit Identification Code (UIC) that uniquely identifies the unit submitting the requisition. 957 unique unit identification codes are identified from the Demand History file. The Defense Automatic Addressing System Center [DAASC, 2000] (a web site maintained by Defense Logistics Agency) is used to locate each unit in order to group the customers by geographic proximity. The city, state, zip code and country information for 807 of the original 957 units are thus determined.

We assume that 40 of the 150 unidentified unit identification codes are decommissioned units that have closed since 31 March 1999. The remaining 110 unidentified entities are deployed units, and their respective locations are unknown. In addition to those 150 unidentified units, we delete 46 unit identification codes representing Navy Reserve Centers, Navy Reserve Officers Training Corps units and other training commands that do not generate much demand. This leaves 761 customers for modeling purposes.

We use the three-digit zip code aggregation technique mentioned in Chapter 2 for domestic customers. Those customers whose shipping zip codes have the same first three digits are aggregated into one demand region. We create 74 demand regions with this method. The dominant customer location in each demand region is chosen as its cluster center. The 23 demand regions listed in Table 3.1 include more than one major customer, so they are divided into two or more regions by direction of NAVICP so as to retain visibility of major customers. This aggregation reduces 524 domestic customers to 103 demand regions.

Transportation cost from continental US to an overseas country does not change significantly between cities in that country. Also, the transportation rates between cities in overseas countries are not readily available. Therefore, we aggregate overseas customers into their home countries (e.g., Milldenhall and Glasgow are grouped as Great Britain). Seven demand regions in Hawaii and one demand region in Guam and in Puerto Rico are treated as overseas customers. This aggregation creates 23 overseas demand regions from 137 overseas customers. Appendix A lists the 126 demand regions worldwide.

DEMAND REGION	STATE	ZIP CODE	DEMAND REGION	STATE	ZIP CODE
Cutler	ME	**04626**	Pensacola	FL	**32508**
Winter Harbor	ME	**04693**	Milton	FL	**32570**
Indian Head	MD	**20640**	Jacksonville	FL	**32212**
Patuxent River	MD	**20670**	Cecil Field	FL	**32215**
NAVAIR	MD	**20688**	Mayport	FL	**32228**
Fort Meade	MD	**20755**	Cape Canaveral	FL	**32920**
Andrews AFB	MD	**20762**	Patrick AFB	FL	**32925**
West Bethesda	MD	**20817**	Stennis Space Center	MS	**39522**
Bethesda	MD	**20889**	Pascagoula	MS	**39567**
Chesapeake	VA	**23320**	Ingleside	TX	**78362**
Wallops Island	VA	**23337**	Kingsville	TX	**78363**
Suffolk	VA	**23435**	Fallbrook	CA	**92028**
Virginia Beach	VA	**23460**	Camp Pendleton	CA	**92055**
Norfolk	VA	**23511**	Point Mugu	CA	**93042**
Little Creek	VA	**23521**	Port Hueneme	CA	**93043**
Newport News	VA	**23607**	Edwards AFB	CA	**93523**
Yorktown	VA	**23691**	China Lake	CA	**93555**
Cherry Point	NC	**28533**	Moffett Field	CA	**94035**
Jacksonville	NC	**28545**	San Bruno	CA	**94066**
SUBASE San Diego	CA	**92106**	Everett	WA	**98201**
San Diego	CA	**92132**	Oak Harbor	WA	**98278**
North Island	CA	**92135**	Orange Park	FL	**32073**
NAVSTA San Diego	CA	**92136**	St Augustine	FL	**32085**
Miramar	CA	**92145**	Charleston	SC	**29405**
Bremerton	WA	**98314**	North Charleston	SC	**29419**
Silverdale	WA	**98315**	Goose Creek	SC	**29445**

Table 3.1: Three-digit Zip Code Clusters that have been Subdivided to Retain Major Customer Visibility

Demand regions within solid lines share the same three-digit zip code. They are major customer locations, so are not aggregated. For instance, 93042 and 93043 has the same three-digit zip code, but has been subdivided into two clusters as Point Mugu, CA, and Port Hueneme, CA.

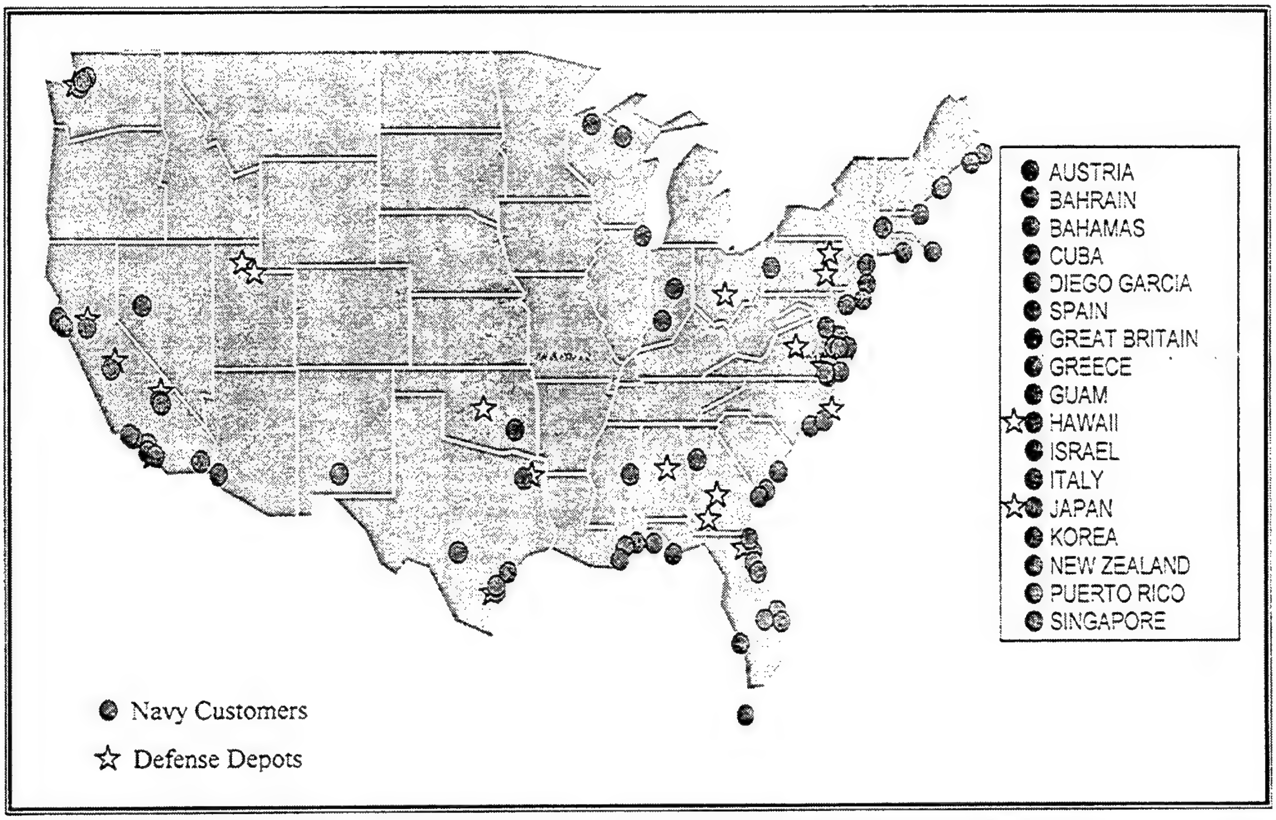

Figure 3.1: Aggregated Navy Demand and Defense Depot Locations
[After Stanton, 2000]

C. DISTRIBUTION CENTERS

Every requisition made by the Navy contains a Routing Identification Code (RIC) that identifies the activity for which the requisition is originally submitted. The routing identification code uniquely identifies a distribution center or inventory control point. From the Demand History file, 155 routing identification codes are identified with unit name, city, state, zip code and country. We have reduced this number by direction of NAVICP to only 22 DLA Defense Distribution Depots as distribution centers.

DLA charges the Navy a standard distribution fee for utilizing its depots (i.e., the DLA charges the same holding and processing fees, regardless of where in the world the

Navy chooses to store its items). The current holding and processing rates are given in Table 3.2.

Processing Rates	Receipts	Issues On-Base	Issues Off-Base
Bin	$24.55	$13.95	$17.18
Medium Bulk	$38.59	$31.10	$38.49
Heavy Bulk/Hazardous	$63.29	$57.34	$88.88
Transshipments	$5.25		

Storage Rates (S/cubic ft)
Covered Area: 0.83   Open Area: 0.17

Table 3.2: Defense Distribution Center Fiscal Year 2000 Distribution Rates
Receipt is the charge to receive and stow the items in a depot. Issues On-Base is the charge for a customer to come and pick up an item. Issues Off-Base is the charge to pick, pack, and ship material to a customer. Deliveries to the afloat units while in port for overhaul or maintenance go to a dedicated depot to be held for that unit until it needs the item. When the depot delivers the item to the unit, the depot charges transshipment cost. [Emerick, 2000]. For instance, suppose the Navy orders ten items, shipped at once, and stored in bins in the covered area of a DLA depot. DLA charges the Navy $24.55 annually for receiving and stowing those items plus $0.83 per cubic foot for storage. If NAVICP requests DLA to ship two of these items to a customer, then DLA charges the Navy $13.95 more.

Because all inventory handling and storage fees are the same at every depot worldwide, from a modeling standpoint, there is no need to determine the cheapest depot. Instead of standard costs, this study uses the *Processing Composite Costs*, or actual charges for receiving, storing and issuing items at each DLA depot. The Processing Composite Costs contain information for FY97, FY98 and FY99 (provided by the sponsor, NAVICP Code 041). The depot costs used in this thesis are calculated as: Depot cost = (3 * FY97 value + 12 * FY98 value + 3 * FY99 value)/18.

The depot cost for Ogden, UT (DDOU) is assumed to be the same value for costs incurred at Hill, UT (DDHU). We assume the average composite value for both Pearl Harbor, HI (DDPH) and Yokosuka, JPN (DDYJ).

Because NAVICP shares storage space with other military services in the DLA depots, an estimation of the amount of capacity on hand to NAVICP is not available. Information gathered from Defense Distribution Center in New Cumberland, PA, has determined that there is no fixed assignment or ceiling on capacity used by NAVICP [Wayne, 2000]. We assume that NAVICP can utilize the total amount of space in any DLA depot.

D. WHOLESALE ITEMS

Examination of the demand history data reveals a registered demand of 32,521 unique items over the 18-month period.

E. TRANSPORTATION MODES, METHODS, AND COSTS

The DLA charges the Navy a standard fee for transporting an item regardless of where or how that item is shipped. However, transportation costs are considered as discretionary while optimizing the flow of product through the distribution network.

Every Navy customer submitting a request uses a priority code (from priority-1 to priority-35) on the requisition form. A priority code determines the time period within which the requisition must be fulfilled by NAVICP. To determine the discretionary costs, first we group the requisition priorities into issue groups as follows:

Priority-1 through priority-3 is aggregated as issue group-1.

Priority-4 through priority-9 is aggregated as issue group-2.

Priority-10 and above is aggregated as issue group-3.

Issue group-1 must be delivered the next day, issue group-2 must be delivered in 5 days, and issue group-3 must be delivered in 30 days.

Then, we simplify the transportation modes and calculate associated costs. Transportation costs for the continental US are computed from a "Freight Forwarding Matrix," (Appendix C) which Naval Transportation Support Center, Norfolk, VA, uses for planning purposes, and from contracts made by Air Mobility Command (AMC) with United Parcel Service [UPS, 1998], DHL Worldwide Express [DHL, 1998], and Federal Express Corporation [FedEx, 1998]. The computed transportation rates within the continental US are shown in Table 3.3.

Issue group-1		Issue group-2		Issue group-3
Weight and Distance	**Cost**	**Distance**	**Cost**	**Cost**
distance <= 250	0.0394*weight	distance <= 1500	(1.57/40000)*weight	(1.57/40000)*weight
weight <= 150 & Distance > 250	0.81*weight			
weight > 150 & Distance > 250	150 ÷ (1.57/40000)*weight	distance > 1500	1*weight	

Table 3.3: Continental US Distribution Rates

If an item weighing 100 lbs. is shipped within 250 miles with issue group-1, the transportation cost will be 0.0394x100 = $3.94.

Table 3.4 shows the transportation costs computed from the same contracts indicated above, and from AMC transportation rates [DoD Rates, 2000].

Issue group-1		Issue group-2 or Issue group-3	
Country	**Cost**	**Weight**	**Cost**
AUS or NZL	1.72*weight	weight < 439	0.0006035840*weight*distance
BHR or GRC or ISR	2.2*weight	weight < 1099	0.0005428040*weight*distance
BHS or CUB or DGC	0.82*weight	weight < 2199	0.0004833975*weight*distance
ESP or GBR or ITA	1.66*weight	weight < 3599	0.0004218870*weight*distance
JPN or KOR or SGP or GUAM	1.68*weight	weight ÷	0.0003714355*weight*distance
HAWAI or PUERTO RICO	0.81*weight		
If distance <= 20 then cost = 0			

Table 3.4: Overseas Distribution Rates

If an item weighing 100 lbs. is shipped from Norfolk, VA, to Naples, Italy, with issue group-1, the transportation cost will be 1.66x100 = $166.

IV. NAVY INVENTORY POSITIONING MODEL

A. PROBLEM DESCRIPTION AND ASSUMPTIONS

The objective of this thesis is to develop and solve a model that determines the optimal strategic distribution network for Navy wholesale inventory. The model minimizes the distribution cost by repositioning the Navy wholesale inventory. The user must define the following entities:

- Customers,
- Depots with capacities and depot costs,
- Items with weights and volumes,
- Mileages between customers and depots, and
- Transportation rates.

The following are assumptions made to simplify the problem and make it solvable:

1. Unchanging Demand Locations

The demand history file includes requisitions from afloat units as well as from shore facilities. In the real world, a deployed unit may submit a requisition from an offshore location rather than from its homeport. Nevertheless, while actual demand records taken from an 18-month period are used as the data source in this thesis, we assume that demand has originated from the customer's homeport address.

2. Transportation Modes

This effort does not consider items requiring special handling, such as hazardous material, toxic chemicals, etc. We assume that all material can be shipped via any mode of transportation.

3. Availability of Each Depot to Every Customer

This thesis does not consider special handling or storage requirements for particular items. It is assumed that any item can be stored in any DLA depot, and that any depot can deliver to any Navy customer.

4. Total Usable Capacity At Each Depot

Although the exact capacities of each depot are known, DLA shares these depots with all branches of the military. There are no specific storage limitations for the Navy and the other services. Depot usage varies greatly for all services from facility to facility. Historical records show that NAVICP uses only 12% of the indoor capacity and 8% of the outdoor capacity of the total volume flowing through DLA [Wayne, 2000]. The DLA has never refused to store an item at a particular depot, unless that depot was already filled to capacity. Thus, we assume that the DLA can accommodate any storage request.

5. Multiple Sourcing

NAVICP plans to source each customer from multiple depots for a particular item in the near future. This model uses multiple sourcing, so a request for a particular item can be sourced anywhere there is availability.

B. A MODEL TO MINIMIZE COST BY REPOSITIONING THE NAVY WHOLESALE INVENTORY

This section describes a distribution network optimization model. The primary decision variable in the model is the quantity of an item transported from a depot to a customer via some issue group level.

1. Objective

The purpose of the optimization model is to minimize the total operating cost plus any policy penalties.

2. Constraints

The model's constraints can be grouped into three categories: demand satisfaction, depot indoor capacity, and depot outdoor capacity.

a. Demand Satisfaction Constraint:

This constraint ensures that each order is transported to the required destination within the designated time (shipment issue group).

b. Depot Indoor Capacity Constraint:

This constraint penalizes the objective function if the flow going into a depot is greater than the indoor capacity of that depot.

c. Depot Outdoor Capacity Constraint:

This constraint limits throughput to the depot's maximum available capacity, indoor plus outdoor.

3. Linear Program

a. Indices

i : The set of items (32,521 unique wholesale items)

d: The set of potential distribution depots (22 DLA depots)

p: The set of issue groups (P1, P2, P3)

c: The set of customer groups (126 aggregated demand regions)

b. *Data (units in parenthesis)*

vol$_i$: Volume of item *i* (cubic feet/unit)

incap$_d$: Indoor throughput capacity of depot *d* (cubic feet)

outcap$_d$: Outdoor throughput capacity of depot *d* (cubic feet)

dem$_{i,p,c}$: Annual demand for item *i* of priority *p* by customer *c* (unit)

pcost$_{i,d}$: Processing cost of item *i* through depot *d* (dollar/unit)

tcost$_{i,d,c,p}$: Cost to deliver item *i* from depot *d* to customer *c* with priority *p* (dollar/unit)

pen : Penalty for outdoor storage (dollar/cubic feet)

c. *Positive Variables*

X$_{i,d,c,p}$: Outbound flows of item *i* from depot *d* to customer *c* with priority *p* (unit)

OVERCAP$_d$: Amount of item stored outdoor at depot *d* (cubic feet)

d. *Formulation*

<u>MIN</u>

$$\sum_{i,d,c,p} pcost_{i,d} X_{i,d,c,p} + \sum_{i,d,c,p} tcost_{i,d,c,p} X_{i,d,c,p} + \sum_{d} penOVERCAP_d$$

<u>Subject to</u>

$$\sum_{d} X_{i,d,c,p} \geq dem_{i,c,p} \qquad , \forall_{i,c,p}$$

$$\sum_{i,c,p} vol_i X_{i,d,c,p} - OVERCAP_d = incap_d \qquad , \forall_d$$

$$OVERCAP_d \leq outcap_d \qquad , \forall_d$$

$$X_{i,d,c,p} \geq 0 \qquad , \forall_{i,d,c,p}$$

4. Heuristic Algorithm

The model, with more than 270 million decision variables and 12 million constraints is solved with a heuristic algorithm implemented in JAVA [Sun Microsystems Inc., 1998]. It takes approximately 45 minutes to solve the problem that minimizes the transportation and depot costs, on a personal computer with a Pentium III processor at 500 megahertz and with 128 megabytes of RAM.

The program uses four transaction files to generate the inventory positioning scheme. The files should be named as indicated, and be saved in the same directory with the program file.

- "ITEM.txt": This file contains the demand records for aggregated customers. The file is constructed from the Demand History File by aggregating the individual demands to demand regions. The file format is string (the item's NIIN), string (the item's supply class), long (item quantity), integer (issue group), double (item weight), double (item volume), string (demand region).

- "CUSTOMER.txt": This file contains aggregated customers list constructed from demand history file. CUSTOMER.txt is in a format of string (customer).

- "DEPOT.txt": This file contains depot names, capacities, and depot costs in a format of string (depot name), double (depot capacity), double (depot cost). We use indoor capacities for each depot as depot capacities.

- "DISTANCE.txt": These files contain the mileages between demand regions and depots. The data format is string (demand region), string (depot name), double (mileage).

C. RESULTS

In this section, various scenarios are tested to track the behavior of the flow of the material through the network.

1. Minimizing Transportation and Depot Costs

We consider all available data and run the model. The model takes the customer's demands from the "ITEM.txt" file one by one, and assigns a depot which has the least expensive distribution cost (includes transportation cost from customer to depot and the depot throughput cost), and available storage capacity for that demanded item. If there is more than one depot with the same distribution cost, the item is assigned to the nearest depot.

	Continental US	Overseas	Total
Shipment Size	24,161.37 Klb	5,288.97 Klb	29,450.34 Klb
Mileage	77,417.25 ml	76,300.40 ml	153,717.65 ml
Weight*Mileage	10,460,394.65 Klbml	9,746,609.73 Klbml	20,207,004.38 Klbml
Transportation Cost	$2,356.99	$2,479.83	$4,836.82
Transportation Modes and Sizes			
Commercial Air	2,946.56 Klb		
Air Mobility Command	744.45 Klb		
Less than truck load	16,032.83 Klb		
Truck load	9,726.51 Klb		

Table 4.1: Throughput Volume in Continental US and Overseas that Minimizes Transportation and Depot Costs

The entries show that 10,460,394.65 Klbml (thousand pound-miles) is shipped within the continental US, and 9,726.51 Klb. of items are shipped in full truckloads.

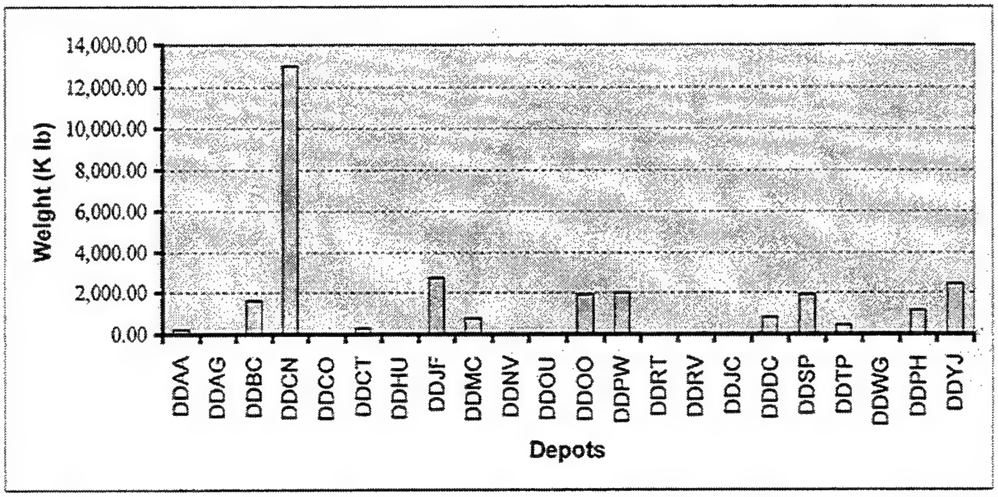

Figure 4.1: Throughput Volume that Minimizes Transportation and Depot Costs
Cherry Point, NC, is utilized heavily-- 44% of items in pounds are distributed through this depot. i.e., 12,980.63 Klb. of items are stored at Cherry Point, NC (DDNC), whereas nothing is stored at DDAG, DDCO, DDHU, DDNV, DDOU, DDRT, DDRV, DDJC or DDWG. (Depot identifiers are defined in Table 4.2 and in Appendix B.)

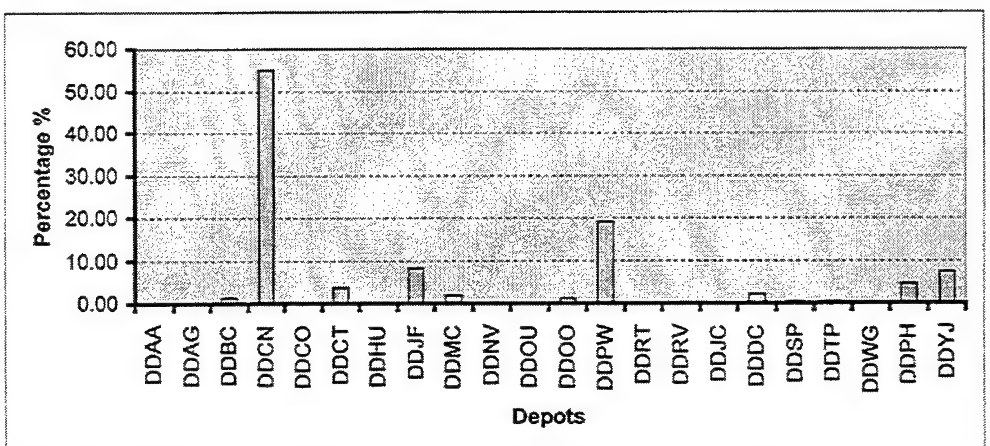

Figure 4.2: Depot Utilization that Minimizes Transportation and Depot Costs
Capacity usage as a percentage of indoor capacity at each depot. All depots except Cherry Point, NC, (DDCN) are utilized 20% below their indoor capacities.

Table 4.2 shows the quantity of Navy wholesale inventory positioned at each depot.

Depot		Weight (Klb)	Volume (K cbft)	Indoor Cap. (K cbft)	Utilization % of indoor cap.
DDAA	Anniston, AL	232.60	22.11	16,137	0.14
DDAG	Albany, GA	6.22	0.87	17,091	0.01
DDBC	Barstow, CA	1,641.67	172.36	12,241	1.41
DDCN	Cherry Point, NC	12,980.63	1,728.78	3,143	55.00
DDCO	Columbus, OH	0.00	0.00	12,771	0.00
DDCT	Corpus Christi, TX	309.73	66.63	1,806	3.69
DDHU	Hill, UT	0.00	0.00	16,721	0.00
DDJF	Jacksonville, FL	2,756.36	379.36	4,610	8.23
DDMC	Mcclellan, CA	743.36	134.88	7,380	1.83
DDNV	Norfolk, VA	0.00	0.00	17,937	0.00
DDOU	Ogden, UT	0.00	0.00	1,333	0.00
DDOO	Oklahoma City, OK	1,933.16	231.98	18,541	1.25
DDPW	Puget Sound, WA	2,025.04	400.16	2,101	19.05
DDRT	Red River, TX	0.00	0.00	27,702	0.00
DDRV	Richmond, VA	0.00	0.00	28,189	0.00
DDJC	San Joaquin, CA	0.00	0.00	53,420	0.00
DDDC	San Diego, CA	815.14	179.16	9,058	1.98
DDSP	Susquehanna, PA	1,908.93	238.70	59,337	0.40
DDTP	Tobyhanna, PA	423.30	61.52	13,202	0.47
DDWG	Warner Robins, GA	71.91	10.29	17,448	0.06
DDPH	Pearl Harbor, HI	1,164.33	229.88	5,071	4.53
DDYJ	Yokosuka, JA	2437.98	345.97	4,733	7.31
	Total	29,450.35	4202.65	349972.00	1.20

Table 4.2: Depot Utilization that Minimizes Transportation and Depot Costs
The Navy wholesale inventory, including only the items requested at least once during a 18-month period, utilizes 1.20% of total indoor capacity at 22 defense depots.

Although the depots in Norfolk and San Diego are located close to Navy bases, and the depots in San Joaquin and Susquehanna are highly automated, they are not the most highly utilized. Cherry Point, NC, having the most inexpensive depot cost, and being within 250 miles (assumed as available for ground transportation for issue group-1) to high demand regions such as Norfolk, VA, makes this depot the least expensive in the distribution network.

Regardless of issue groups, a customer demand is shipped via truck when the order has been filled by a depot located within 20 miles of that customer. Thus, those depots within 20 miles of major customers are highly desirable if their depot costs are not

significantly higher. Figure 4.3 shows the ratio of those customer demands located within 20 miles of a depot to the total throughput volume of that depot.

Depot		Weight (Klb)	Total Weight	Weight Ratio	Volume (K cbft)	Total Volume	Volume Ratio
DDAA	Anniston, AL	0.00	232.60	0.00	0.00	22.11	0.00
DDAG	Albany, GA	0.00	6.22	0.00	0.00	0.87	0.00
DDBC	Barstow, CA	0.00	1,641.67	0.00	0.00	172.36	0.00
DDCN	Cherry Point, NC	806.78	12,980.63	0.06	67.61	1,728.78	0.04
DDCO	Columbus, OH	0.00	0.00	0.00	0.00	0.00	0.00
DDCT	Corpus Christi, TX	217.03	309.73	0.70	33.22	66.63	0.50
DDHU	Hill, UT	0.00	0.00	0.00	0.00	0.00	0.00
DDJF	Jacksonville, FL	1,935.53	2,756.36	0.70	260.44	379.36	0.69
DDMC	Mcclellan, CA	0.00	743.36	0.00	0.00	134.88	0.00
DDNV	Norfolk, VA	0.00	0.00	0.00	0.00	0.00	0.00
DDOU	Ogden, UT	0.00	0.00	0.00	0.00	0.00	0.00
DDOO	Oklahoma City, OK	0.00	1,933.16	0.00	0.00	231.98	0.00
DDPW	Puget Sound, WA	1,372.77	2,025.04	0.68	303.41	400.16	0.76
DDRT	Red River, TX	0.00	0.00	0.00	0.00	0.00	0.00
DDRV	Richmond, VA	0.00	0.00	0.00	0.00	0.00	0.00
DDJC	San Joaquin, CA	0.00	0.00	0.00	0.00	0.00	0.00
DDDC	San Diego, CA	0.76	815.14	0.00	0.01	179.16	0.00
DDSP	Susquehanna, PA	63.71	1,908.93	0.03	45.31	238.70	0.19
DDTP	Tobyhanna, PA	0.00	423.30	0.00	0.00	61.52	0.00
DDWG	Warner Robins, GA	0.00	71.91	0.00	0.00	10.29	0.00
DDPH	Pearl Harbor, HI	1,158.54	1,164.33	1.00	229.60	229.88	1.00
DDYJ	Yokosuka, JA	2,314.14	2,437.98	0.95	334.18	345.97	0.97
	Total	7,869.26	29450.36		1,273.78	4,202.65	

Table 4.3: Ratio of Customer Throughput within 20 Miles to a Depot to All Throughput at that Depot while Minimizing Transportation and Depot Costs

70% in weight and 50% in volume of throughput at Corpus Christi, TX, (DDCT) is for customers within 20 miles.

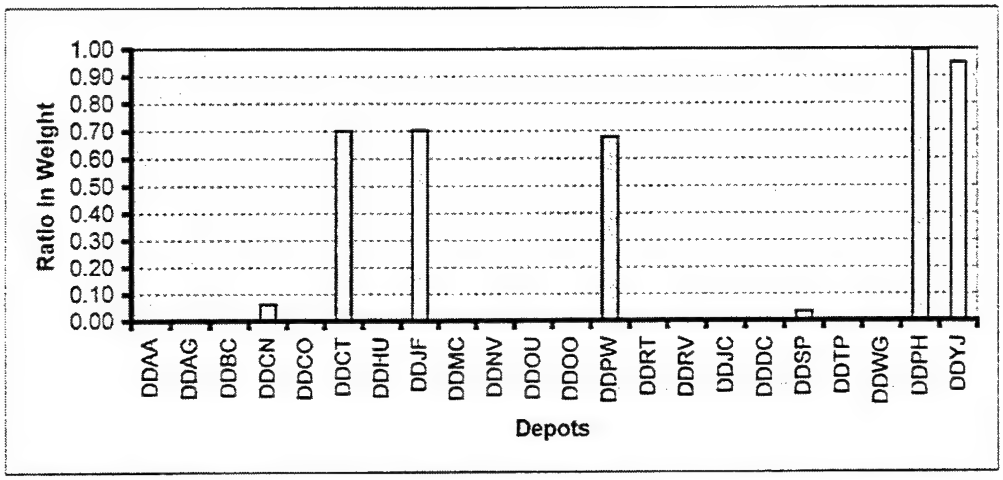

Figure 4.3: Ratio of Customer Throughput within 20 Miles to a Depot to All Throughputs at that Depot while Minimizing Transportation and Depot Costs

Five depots: Corpus Christi, TX; Jacksonville, FL; Puget Sound, WA; Pearl Harbor, HA; and Yokosuka, Japan are predominantly utilized by local customers. For instance, 70% of Corpus Christi, TX, (DDCT) throughput is for those customers located within 20 miles of Corpus Christi, TX.

The solution details show the depots assigned for each item in the history demand file and the transportation cost as text file like that shown in Table 4.4. The total cost can be computed by adding the associated depot cost to the transportation cost.

NIIN	Supply Group	Depot	Demand Region	Issue Group	Quantity	Transportation Cost
000011632	5960	DDCN	32508	1	1	$31.42
			39567	1	1	$31.42
			92136	1	1	$31.42
		DDSP	17055	1	1	$1.52
		DDYJ	JPN	1	1	$0.00
000011673	4820	DDCN	23460	1	39	$21.88
			23511	1	1	$0.54
		DDDC	93042	1	2	$1.12
		DDJF	32085	1	1	$0.56
			32212	1	3	$1.68

Table 4.4: Assigned Depots and Corresponding Transportation Costs for Each Item while Minimizing Transportation and Depots Costs

Item "000011632" requested by "32508" Pensacola, FL, "39567" Pascagoula, MS, "92136" San Diego, CA, "17055" Mechanicsburg, PA, and "JPN" Japan should be located in DDCN for "325008", "39567"and "92136"; in DDSP for "17055"; and in DDYJ for Japan in corresponding quantities.

2. Minimizing Transportation Costs

We now ignore the depot costs and solve the problem with respect to transportation cost only. In commercial air shipment mode, the distance between departure and arrival point is irrelevant, but the weight of the item shipped is significant, as this factor affects transportation cost. This characteristic of air transportation will result in alternate solutions with the same cost. We eliminate this situation by choosing the closest depot if there are alternate solutions.

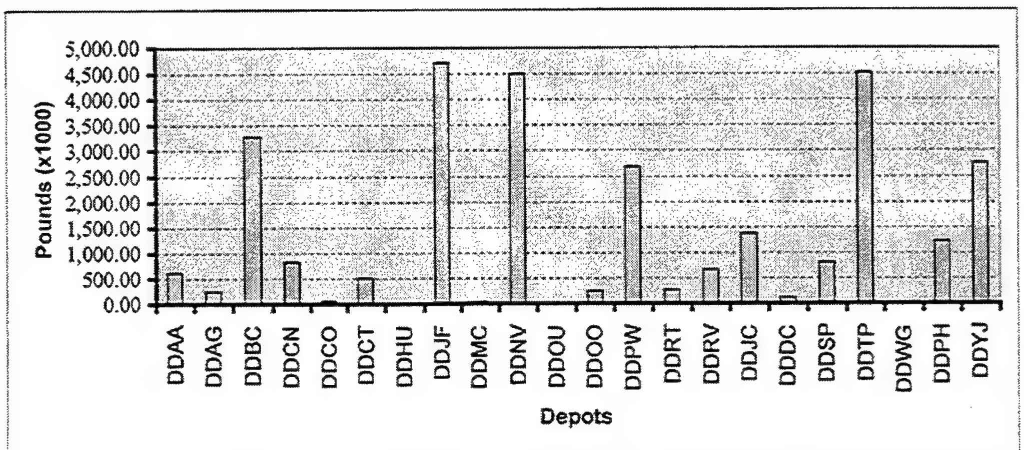

Figure 4.4: Throughput Volume that Minimizes Transportation Costs

In contrast to minimizing transportation and depot costs, depots within close proximity of major customers are highly utilized. For instance, 4,502.89 Klb. of wholesale inventory are stored at Norfolk, VA, (DDNV), whereas nothing is stored at this depot while minimizing only transportation cost.

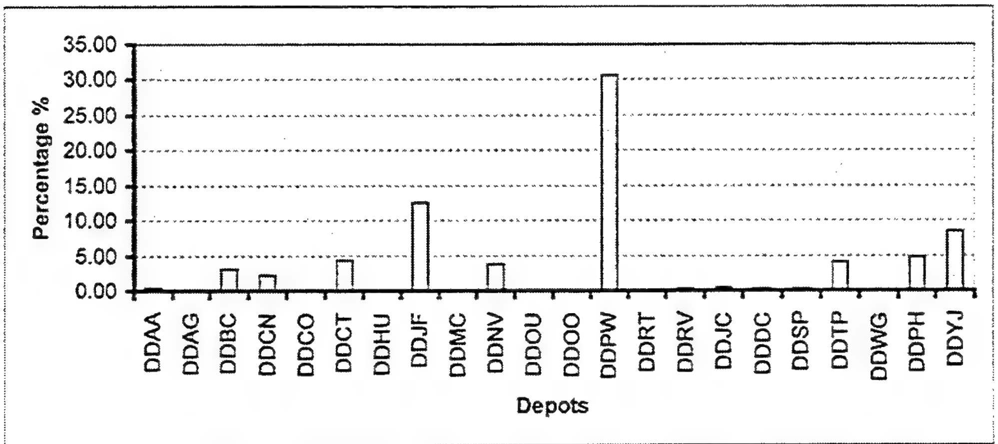

Figure 4.5: Depot Utilization that Minimizes Transportation Costs

Puget Sound, WA (DDPW) is the most highly utilized depot with 30.56% of indoor capacity.

Depot		Weight (Klb)	Volume (K cbft)	Indoor cap. (K cbft)	Utilization % of indoor cap.
DDAA	Anniston, AL	608.57	58.35	16,137	0.36
DDAG	Albany, GA	246.87	25.35	17,091	0.15
DDBC	Barstow, CA	3,273.76	382.38	12,241	3.12
DDCN	Cherry Point, NC	822.55	71.82	3,143	2.29
DDCO	Columbus, OH	66.25	4.30	12,771	0.03
DDCT	Corpus Christi, TX	500.12	79.58	1,806	4.41
DDHU	Hill, UT	0.00	0.00	16,721	0.00
DDJF	Jacksonville, FL	4,712.80	581.75	4,610	12.62
DDMC	Mcclellan, CA	47.03	6.59	7,380	0.09
DDNV	Norfolk, VA	4,502.89	683.69	17,937	3.81
DDOU	Ogden, UT	0.00	0.00	1,333	0.00
DDOO	Oklahoma City, OK	247.85	20.88	18,541	0.11
DDPW	Puget Sound, WA	2,691.00	642.07	2,101	30.56
DDRT	Red River, TX	265.52	43.14	27,702	0.16
DDRV	Richmond, VA	677.65	75.66	28,189	0.27
DDJC	San Joaquin, CA	1,374.61	191.18	53,420	0.36
DDDC	San Diego, CA	105.40	30.40	9,058	0.34
DDSP	Susquehanna, PA	795.75	132.51	59,337	0.22
DDTP	Tobyhanna, PA	4,517.02	531.69	13,202	4.03
DDWG	Warner Robins, GA	0.00	0.00	17,448	0.00
DDPH	Pearl Harbor, HI	1,228.87	240.16	5,071	4.74
DDYJ	Yokosuka, JA	2,765.85	401.19	4,733	8.48
	Total	29,450.36	4202.69	349972.00	1.20

Table 4.5: Depot Utilization that Minimizes Transportation Costs

Jacksonville, FL, (DDJF) has the biggest throughput, with 4,712.80 Klb.

	Continental US	Overseas	Total
Shipment Size	24,161.37 lb	5,288.97 lb	29,450.34 lb
Mileage	9565.43 ml	30,215.36 ml	39,780.79 ml
Weight*Mileage	2,434,562.25 lbml	6,638,977.16 lbml	9,073,539.41 lbml
Transportation Cost	$2,252.67	$2,444.83	$4,697.50
Transportation Modes and Sizes			
Commercial Air	2,582.51 lb		
Air Mobility Command	734.81 lb		
Truck within 250 ml	16,387.75 lb		
Truck 250<within<1500 ml	9,745.48 lb		

Table 4.6: Throughput Volume in Continental US and Overseas while Minimizing Transportation Costs

The total shipment mileage is reduced from 153,717.65 miles while minimizing transportation and depot costs, to 39,780.79 miles while minimizing just transportation cost.

3. Minimizing Distance

We now assign the closest depot regardless of transportation and throughput costs.

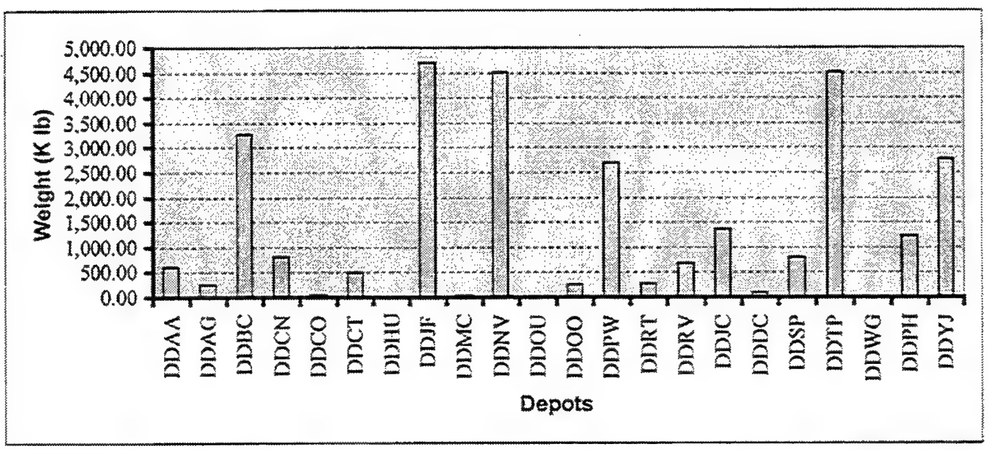

Figure 4.6: Throughput Volume that Minimizes Distance

None of wholesale inventory is stored at Hill, UT; Ogden, UT; or Warner Robins, GA, depots located far from any Navy customers.

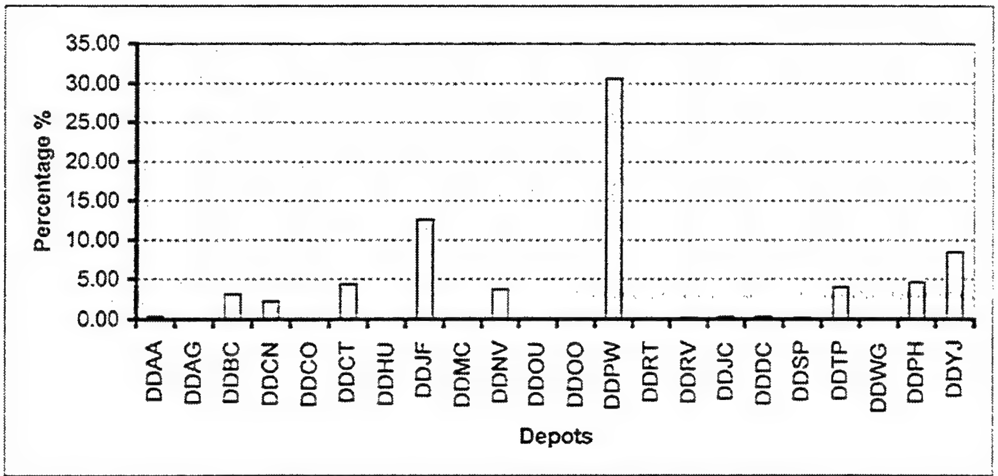

Figure 4.7: Depot Utilization that Minimizes Distance

This solution is identical to that resulting from minimizing transportation cost.

4. Minimizing Transportation and Depot Costs while Delivering Issue Group-2 Next Day

The demand history file contains 109,741 requests from 126 demand regions for 32,521 unique items. 53,324 of these requests are issue group-1, 46,494 of them are issue group-2, and the 9,923 remaining are issue group-3. In this scenario we combine issue group-1 and issue group-2, and deliver both issue groups the next day. The items requested with issue group 1 or 2 weigh 28,280,654 lb, which is 96% of the total weight of wholesale inventory in the demand history file. Items delivered next day are shipped via commercial air. In this case, transportation rates vary by weight, but not by destination, and depot costs have a great impact on assigning a depot for the wholesale inventory.

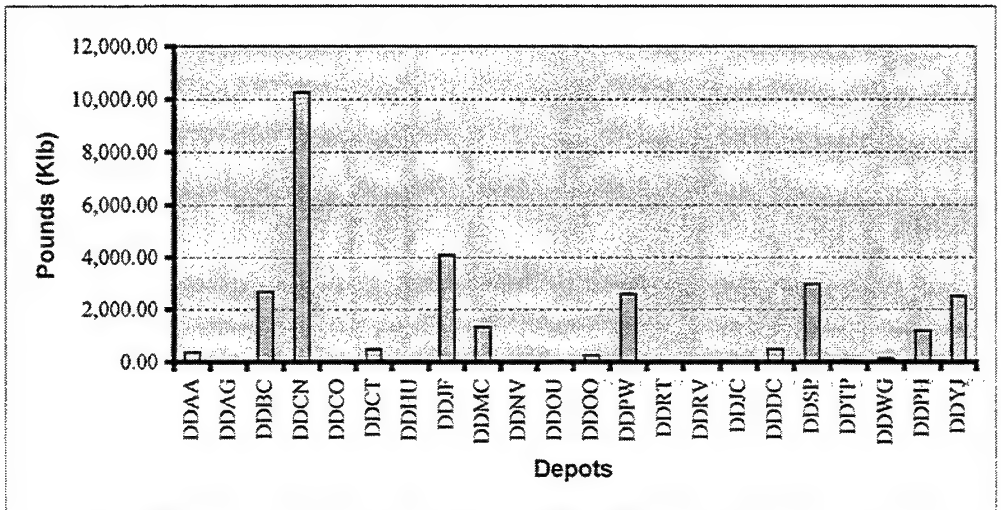

Figure 4.8: Throughput Volume that Minimizes Transportation and Depot Costs while Delivering Issue Group-2 Next Day

Issue group 1 and 2 are combined and delivered the next day. Cherry Point, NC, has the least expensive depot cost, so it is utilized heavily. 34.9% of items in pounds are assigned to this depot.

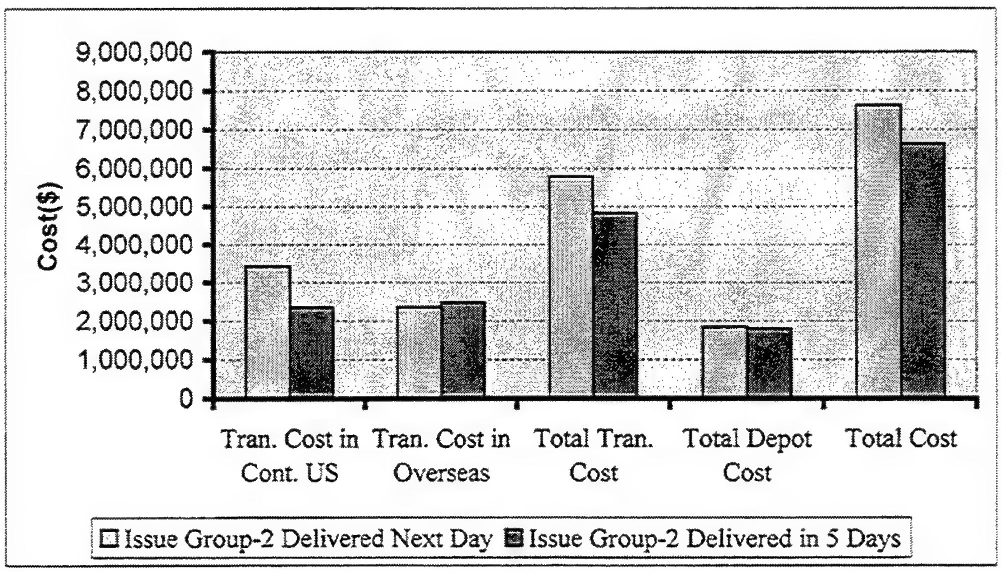

Figure 4.9: Transportation and Depot Costs while Delivering Issue Group-2 Next Day

Delivering Issue Group-2 items the next day rather than within five days does not increase the total depot cost much, but increases the total transportation cost by 20% and the total cost by 15%.

5. Restricting the Maximum Number of Depots Stocking Each Item

We restrict the maximum number of depots stocking each item and minimize transportation and depot costs. The calculated total costs are shown in Figure 4.10.

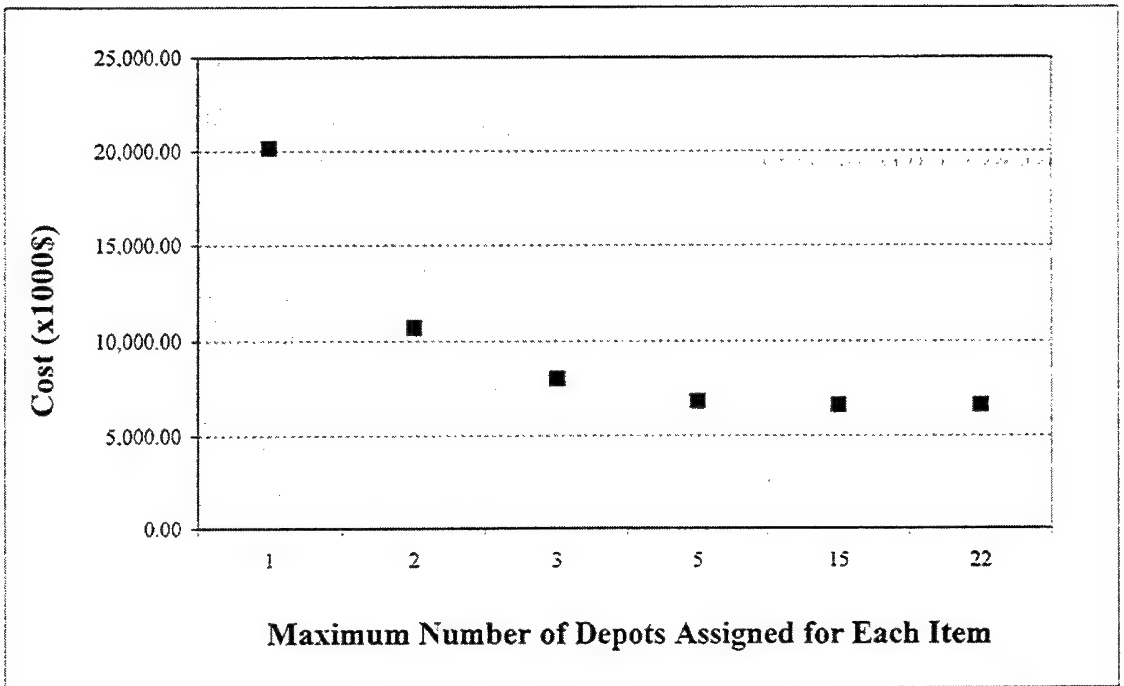

Figure 4.10: Cost vs. Maximum Number of Depots Assigned for Each Item while Minimizing Transportation and Depot Costs

Storing an item in just one depot increases the total distribution cost drastically. The cost decreases quickly as the number of depot locations is increased. The absolute minimum distribution model cost occurs when as many as 15 depots store each item, so dispersing the number of depots beyond 15 does not further reduce distribution cost. For practical purposes, and considering the fixed cost of locating inventory at each depot considered here, three depot locations appear to be ideal.

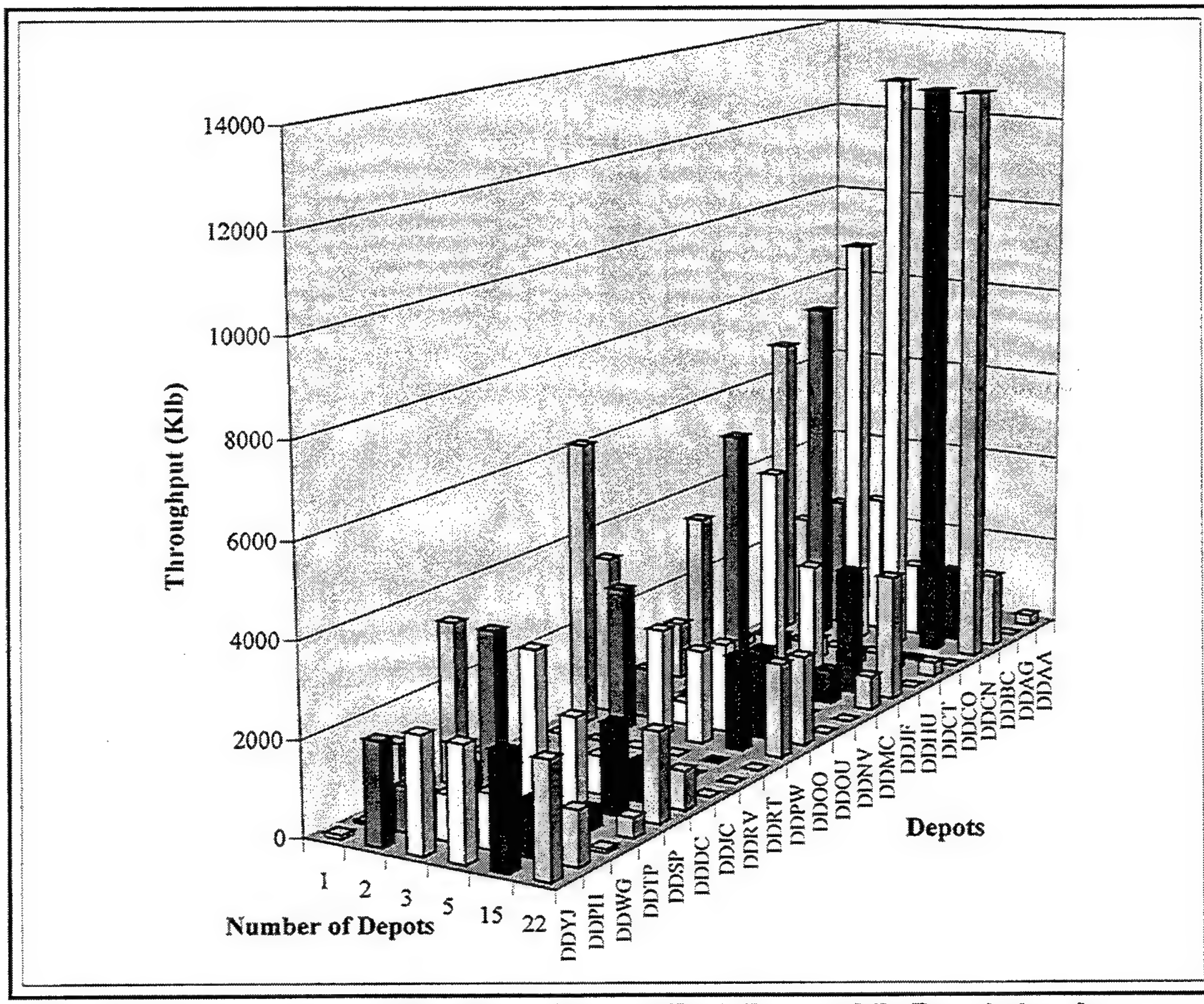

Figure 4.11: Throughput of Individual Items at Each Depot while Restricting the Number of Depots that can Handle Each Item in Minimizing Transportation and Depot Costs Scenario

Cherry Point, NC, has the lowest depot cost. This attracts 44.6% of throughput (13,132 Klb) through Cherry Point, NC, when we restrict the number of depots to 5. Utilization of most of other depots except Cherry Point, NC, decreases when more depots are admitted.

6. Restricting the Maximum Number of Depots Stocking Each Item Group

In lieu of a product aggregation, we use the supply group, the first two digits of the supply class, to identify major material groupings.

We aggregate the 32,521 individual items into 64 item-groups, and run the model restricting the maximum number of depots that may store each item group, and minimize transportation and depot costs. The calculated total costs are shown in Figure 4.12.

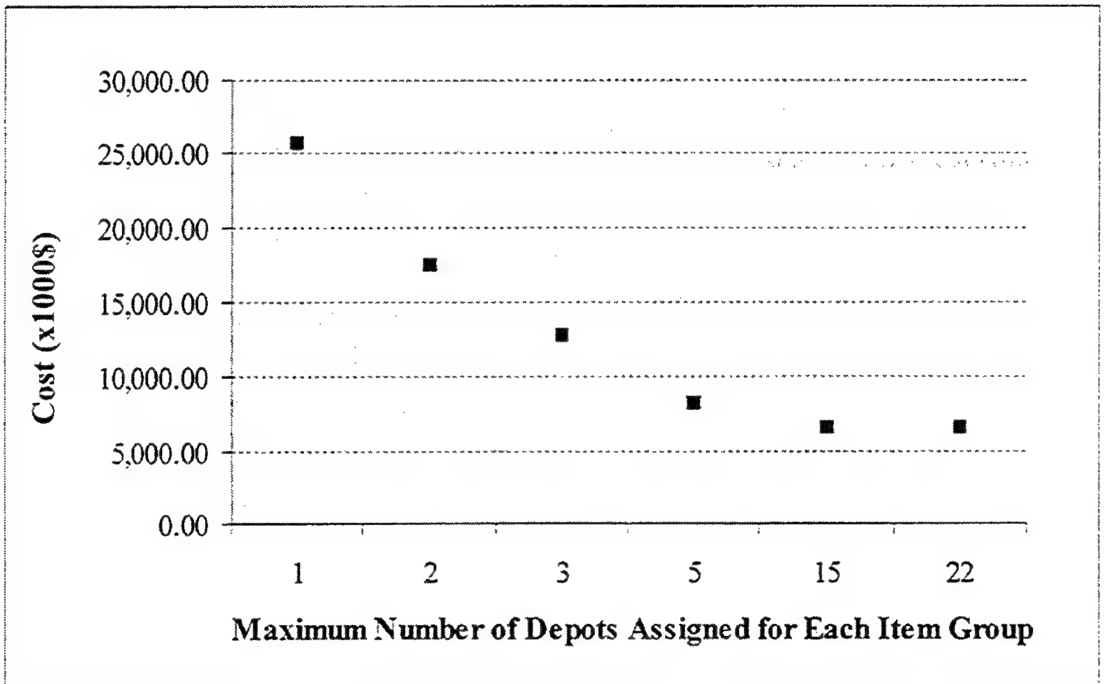

Figure 4.12: Cost vs. Maximum Number of Depots Assigned for Each Item Group while Minimizing Transportation and Depot Costs

Restricting the number of depots for each item group increases the cost more than for restricting depots for individual items. Cost is essentially minimized after five depots, rather than after three depots for individual items. The absolute minimum distribution model cost occurs at 15 depots, as is the case with individual items.

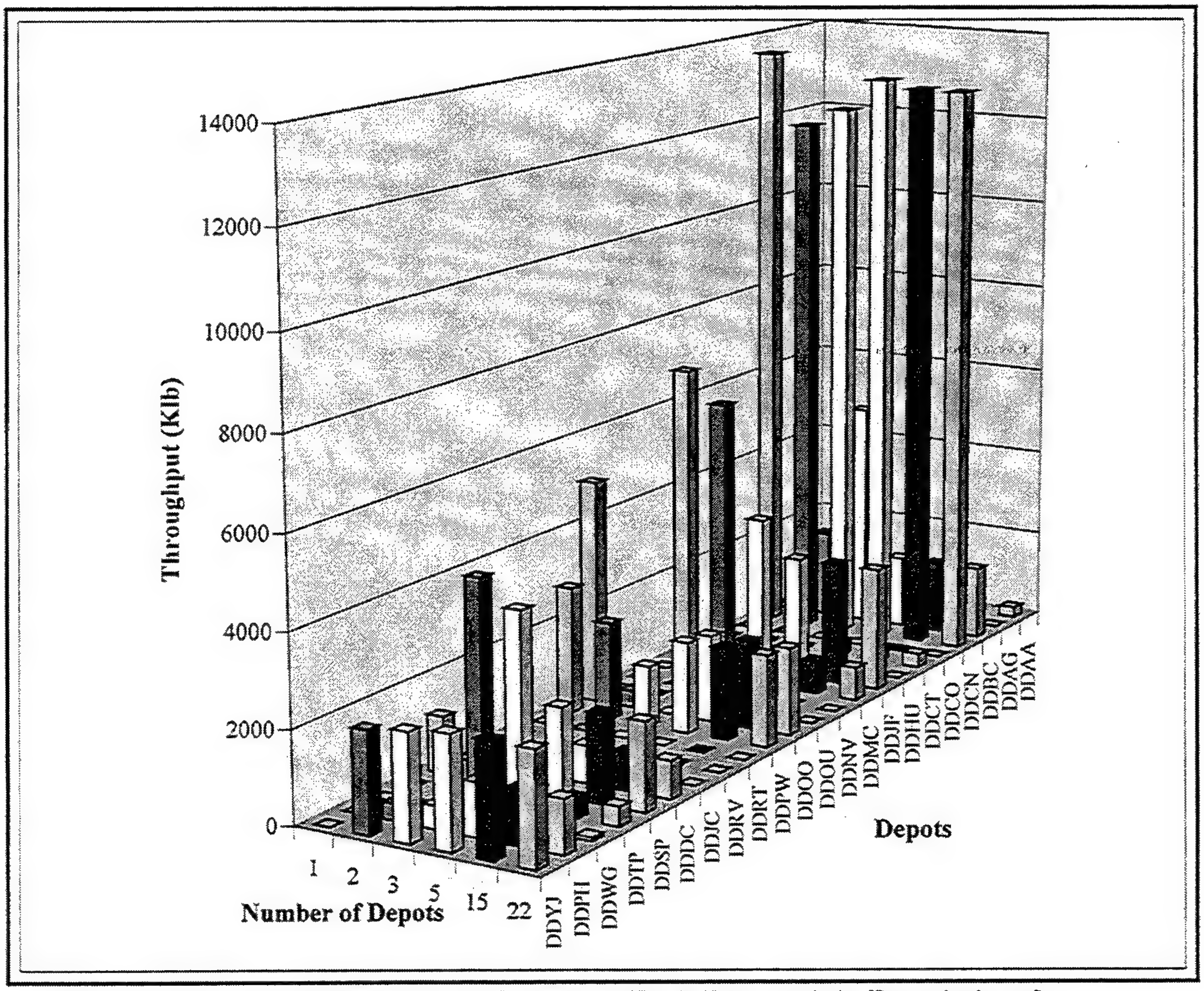

Figure 4.13: Throughput of Item Groups at Each Depot while Restricting the Number of Depots that can Handle Each Item Group in Minimizing Transportation and Depot Costs Scenario

Besides Cherry Point, NC, Jacksonville, FL, Puget Sound, WA, and Susquehanna, PA, are utilized significantly by one-depot and two-depots solutions. Relaxing the use of more depots does not significantly change product flows.

	Item Group	Group Description	First Depot		Second Depot		Third Depot	
			Name	Klb	Name	Klb	Name	Klb
1	10	Weapons	DDCN	66.67	DDCT	22.46	DDYJ	9.06
2	11	Nuclear Ordnance	DDCN	0.77				
3	12	Fire Control Equipment	DDJF	95.35	DDBC	59.01	DDYJ	12.02
4	13	Ammunition and Explosives	DDCN	65.82	DDPH	24.93	DDJF	6.28
5	14	Guided Missile Equipment	DDJF	181.72	DDBC	63.63	DDYJ	13.35
6	15	Acft & Airframe Structural Comp	DDCN	1356.60	DDBC	559.01	DDAG	437.65
7	16	Acft Components & Accessories	DDCN	4378.09	DDBC	1411.83	DDYJ	716.80
8	17	Acft Launcing, Ldg & Gnd Handling	DDCN	224.28	DDYJ	86.09	DDBC	73.27
9	19	Ships, Pontoons, and Floating Docks	DDBC	45.00	DDCN	41.10	DDYJ	13.76
10	20	Ship & Marine Equipment	DDCN	898.25	DDPH	212.65	DDPW	114.46
11	25	Vehicular Equipment Components	DDCN	49.61	DDYJ	26.23	DDBC	8.71
12	26	Tires	DDSP	3211.35	DDBC	1008.11	DDYJ	261.13
13	28	Engines, Turbines & Components	DDJF	2460.65	DDBC	682.99	DDYJ	362.89
14	29	Engine Accessories	DDJF	411.00	DDBC	110.83	DDYJ	57.75
15	30	Mechanical Power Transmission	DDCN	63.27	DDBC	12.66	DDYJ	7.54
16	31	Bearings	DDCN	41.45	DDPW	9.95	DDJF	9.52
17	34	Metalworking Machinery	DDCN	259.03	DDPW	52.65	DDYJ	20.26
18	35	Service & Trade Equipment	DDCN	0.03				
19	36	Special Industry Machinery	DDSP	0.74	DDCN	0.43	DDBC	0.31
20	38	Construction, Mining, Excavating	DDJF	5.68	DDYJ	1.93	DDBC	1.45
21	39	Materials Handling Equipment	DDJF	19.62	DDSP	10.34	DDBC	9.43
22	40	Rope, Cable, Chain, & Fittings	DDSP	6.60	DDCT	1.40	DDYJ	0.82
23	41	Refrigeration & Air Condition Equip	DDCN	86.25	DDBC	25.06	DDYJ	9.45
24	42	Fire Fighting, Rescue & Safety Equi	DDCN	181.56	DDPH	51.21	DDYJ	36.10
25	43	Pumps & Compressors	DDCN	413.56	DDSP	259.71	DDYJ	103.52
26	44	Furnace, Steam, Plant, Drying Equip	DDCN	28.19	DDPH	17.03	DDPW	10.53
27	45	Plumbing, Heating & Sanitation Equi	DDSP	6.50	DDBC	1.48	DDCN	0.78
28	46	Water Purification & Sewage Treat	DDSP	12.77	DDCN	3.23	DDYJ	0.85
29	47	Pipe, Tube & Hose	DDCN	78.72	DDBC	44.89	DDYJ	27.98
30	48	Valves	DDCN	216.70	DDPW	61.45	DDPH	47.38
31	49	Maintenance & Repair Shop Equip	DDCN	251.95	DDBC	117.36	DDYJ	28.42
32	51	Hand Tools	DDCN	51.82	DDPH	27.47	DDDC	13.78
33	52	Measuring Tools	DDCN	0.41	DDPH	0.03	DDYJ	0.03
34	53	Hardware & Abrasive	DDCN	128.06	DDYJ	14.31	DDPH	13.47
35	54	Prefabricated Struc. & Scaffolding	DDCN	2.13				
36	55	Lumber, Millwork, Plywood	DDCN	0.01				
37	56	Construction & Building Materials	DDCN	23.19	DDPW	7.84	DDPH	1.92
38	58	Communication Equipment	DDCN	1035.66	DDBC	280.88	DDYJ	130.06
39	59	Electrical & Electronic Equip/Comp	DDCN	547.76	DDBC	148.11	DDYJ	49.43
40	60	Fiber Optics Matls, Comps, Assys	DDPW	950.28	DDCN	0.24	DDYJ	0.04
41	61	Electric Wire & Power & Distrib.	DDCN	651.08	DDBC	166.60	DDYJ	112.82
42	62	Lighting Fixtures & Lamps	DDCN	44.49	DDMC	11.62	DDYJ	7.10
43	63	Alarm & Signal Systems	DDCN	5.96	DDPW	1.28	DDYJ	0.46
44	65	Medical, Dental & Veterinary Equip	DDCN	0.16	DDYJ	0.09	DDPW	0.08
45	66	Instruments & Laboratory Equip	DDCN	934.80	DDBC	278.07	DDYJ	155.47
46	67	Photographic Equipment	DDCN	8.05	DDMC	1.25	DDYJ	0.82
47	68	Chemicals & Chemical Products	DDCN	29.44	DDPH	3.56	DDJF	2.03

Table 4.7(a): The Best Three Depots to Use for Positioning Each Item Group while Minimizing Transportation and Depot Costs

	Item Group	Group Description	First Depot		Second Depot		Third Depot	
			Name	Klb	Name	Klb	Name	Klb
48	69	Training Aids & Devices	DDSP	30.62	DDOO	4.46	DDYJ	0.48
49	70	General Purpose ADPE, Software	DDJF	197.95	DDBC	21.25	DDYJ	8.68
50	72	Household & Coml Furnishings	DDJF	115.57	DDBC	17.18	DDYJ	16.78
51	73	Food preparation & Serving Equip	DDJF	9.72	DDBC	1.53	DDYJ	0.37
52	74	Office Mach., Visible Record Equip	DDCN	0.13	DDPH	0.02		
53	75	Office Supplies & Devices	DDCN	0.04				
54	76	Books, Maps & Other Publications	DDCN	0.04				
55	77	Musical Inst, Phonog., and Radios	DDCN	0.01				
56	79	Cleaning Equipment & Supplies	DDCN	22.17	DDPW	6.27	DDPH	3.85
57	80	Brushes, Paints, Sealers & Adhesive	DDCN	87.15	DDPW	45.56	DDPH	23.98
58	81	Containers, Packaging & Supplies	DDSP	252.07	DDPW	66.33	DDPH	51.57
59	83	Textiles, Leather, Fur, Notion, Tents	DDCN	15.23	DDPH	7.64	DDPW	1.15
60	84	Clothing & Individual Equipment	DDCN	8.08	DDDC	3.51	DDYJ	1.05
61	91	Fuels, Lubricants, Oils & Waxes	DDCN	1.30	DDPH	0.11	DDJF	0.05
62	93	Nonmetallic Fabricated Materials	DDCN	22.50	DDPH	4.84	DDPW	0.38
63	95	Metal Bars, Sheets & Shapes	DDCN	53.90	DDPW	2.72	DDYJ	2.31
64	99	Miscellaneous	DDPW	0.48	DDCN	0.18	DDPH	0.08

Table 4.7(b): The Best Three Depots to Use for Positioning Each Item Group while Minimizing Transportation and Depot Costs

This table shows the three best depots to use for each item group. If we assign three depots for "Training Aids and Devices", they would be Susquehanna, PA, Oklahoma City, OK, and Yokosuka, Japan, and the throughput for that item group would be 30.62, 4.46, and 0.48 Klb respectively.

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V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This thesis shows how the Navy can reduce supply system distribution costs by considering distribution points that are not collocated with Navy bases but have lower depot costs. This conclusion is the result of an extensive analysis of the DLA's distribution network with different scenarios in which we minimize transportation and depot costs, transportation cost, and distance. In these scenarios we use the following input data: 32,521 individual items requested at least once during an 18-month time horizon, a set of 126 aggregated customers, and 22 defense depots. The scenarios show:

(1) DLA depots currently have excess throughput capacity available;

(2) Depot costs have a great impact on assigning wholesale inventory to depots;

(3) Distributing issue group-2 next day increases the total distribution cost by only 15%;

(4) Deleting depots that are not collocated with Navy bases or that have high depot costs barely affects the total distribution cost; and

(5) Storing items, or even complete item groups at a limited number of depots does not increase transportation and depot costs, and thus may lower full costs including the fixed costs associated with positioning items.

Capacity is not a factor in any of these scenarios. Each depot is utilized below its available capacity. The highest percent of capacity utilization occurs at Cherry Point, NC, with 44% resulting from minimizing transportation and depot costs. The volume of the entire inventory in the demand history file is only 1.20% of the total available depot capacity.

Depot cost is more important than transportation cost. Most of the cost-minimizing total throughput flows through inexpensive depots. The distance between customer and depot does not influence the cost of commercial air shipment (used for issue group-1 items), and truckload rates are considerably lower. Therefore, transportation cost becomes insignificant. Thus, any inexpensive depot becomes a good prospect for storage of lightweight items.

42.37% of requisitions is in issue group-2 and must be delivered within five days. Delivering these items within 24 hours increases the total distribution cost by 15%, but reduces customer wait time significantly.

Depot cost and depot location are major factors in depot assignment. Depots not collocated with Navy bases with above-average costs (such as those in Columbus, OH, Hill, UT, Ogden, UT, Red River, TX), and those collocated with Navy bases and nearby other defense depots with lower costs (e.g., Norfolk, VA, Richmond, VA, and San Joaquin, CA), are not used by the transportation and depot cost scenario.

B. RECOMMENDATIONS

The DLA currently charges NAVICP standard fees for storage, shipping and transportation. These standardized fees signify that no cost savings can be attributed back to NAVICP for optimizing the use of the DLA distribution network. Moreover, because all feasible paths result in the same cost, there is no means to improve the outcomes. The input data (e.g., depot cost and transportation cost) used in the model developed here should be discretionary in order to obtain an optimal result.

Depot capacity limits have not been clearly defined by the DLA. Allowing unlimited use of available capacity could result in filling one of the depots to 100%

capacity with Navy wholesale inventory. For a more reasonable result, the Navy's designated capacity for each depot should be defined, and the volume of items currently in Navy wholesale inventory (but not in the transaction file used here) should be subtracted from the measured capacity of the depot where they are stored.

We use simplified approaches for transportation modes and the development of transportation rates. In this study, we do not consider special transportation modes (e.g., special handling for hazardous material, chemical material, highly perishable material, etc.) or size restriction in any of the transportation mode. This data captures the essential relative relationships among the elements of the DLA distribution network, providing suggestive but not exact answers. The transportation rates and modes used by the DoD should be developed further to provide special transportation modes and size restrictions.

Because of the limited nature of this study and the lack of requisition dates in the demand history file, we have made a rough approximation of ground transportation rates. Every item requested during the 18-month period can be shipped on the same truck independent of time, so the rates are calculated as if every truck is fully loaded. These rates can be estimated more accurately by considering requisition dates for each item.

This study recommends that the data inputs be defined and validated before any optimization solution can be assumed feasible.

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APPENDIX A. DEMAND REGIONS

CONTINENTAL US					
	Demand Region	City	State	ZIP Code	Country
1	Pittsfield	Pittsfield	MA	01201	USA
2	Newport	Newport	RI	02841	USA
3	Portsmouth	Portsmouth	NH	03804	USA
4	Brunswick	Brunswick	ME	04011	USA
5	Bath	Bath	ME	04530	USA
6	Cutler	Cutler	ME	04626	USA
7	Winter Harbor	Winter Harbor	ME	04693	USA
8	Groton	Groton	CT	06349	USA
9	Colts Neck	Colts Neck	NJ	07722	USA
10	Moorestown	Moorestown	NJ	08057	USA
11	Lakehurst	Lakehurst	NJ	08733	USA
12	Newburgh	Newburgh	NY	12550	USA
13	Mechanicsburg	Mechanicsburg	PA	17055	USA
14	Philadelphia	Philadelphia	PA	19111	USA
15	Washington	Washington	DC	20397	USA
16	Indian Head	Indian Head	MD	20640	USA
17	Patuxent River	Patuxent River	MD	20670	USA
18	Solomons	Solomons	MD	20688	USA
19	Fort Meade	Fort Meade	MD	20755	USA
20	Andrews Afb	Andrews Afb	MD	20762	USA
21	West Bethesda	West Bethesda	MD	20817	USA
22	Bethesda	Bethesda	MD	20889	USA
23	Thurmont	Thurmont	MD	21788	USA
24	Quantico	Quantico	VA	22134	USA
25	Arlington	Arlington	VA	22202	USA
26	Dahlgren	Dahlgren	VA	22448	USA
27	Williamsburg	Williamsburg	VA	23185	USA
28	Chesapeake	Chesapeake	VA	23320	USA
29	Wallops Island	Wallops Island	VA	23337	USA
30	Suffolk	Suffolk	VA	23435	USA
31	Virginia Beach	Virginia Beach	VA	23460	USA
32	Norfolk	Norfolk	VA	23511	USA
33	Little Creek	Norfolk	VA	23521	USA
34	Newport News	Newport News	VA	23607	USA
35	Yorktown	Yorktown	VA	23691	USA
36	Portsmouth	Portsmouth	VA	23709	USA
37	Cherry Point	Cherry Point	NC	28533	USA
38	Jacksonville	Jacksonville	NC	28545	USA
39	Charleston	Charleston	SC	29405	USA
40	North Charleston	North Charleston	SC	29419	USA
41	Goose Creek	Goose Creek	SC	29445	USA
42	Beaufort	Beaufort	SC	29904	USA

CONTINENTAL US					
	Demand Region	City	State	ZIP Code	Country
43	Marietta	Marietta	GA	30060	USA
44	Savannah	Savannah	GA	31401	USA
45	Kings Bay	Kings Bay	GA	31547	USA
46	Orange Park	Orange Park	FL	32073	USA
47	St Augustine	St Augustine	FL	32085	USA
48	Jacksonville	Jacksonville	FL	32212	USA
49	Cecil Field	Cecil Field	FL	32215	USA
50	Mayport	Mayport	FL	32228	USA
51	Panama City	Panama City	FL	32407	USA
52	Pensacola	Pensacola	FL	32508	USA
53	Milton	Milton	FL	32570	USA
54	Orlando	Orlando	FL	32828	USA
55	Cape Canaveral	Cape Canaveral	FL	32920	USA
56	Patrick Afb Afloat	Patrick Afb	FL	32925	USA
57	Key West	Key West	FL	33040	USA
58	Macdill Afb	Macdill Afb	FL	33621	USA
59	Meridian	Meridian	MS	39309	USA
60	Stennis Space Center	Stennis Space Center	MS	39522	USA
61	Pascagoula	Pascagoula	MS	39567	USA
62	Indianapolis	Indianapolis	IN	46219	USA
63	Crane	Crane	IN	47522	USA
64	Republic	Republic	MI	49879	USA
65	Clam Lake	Clam Lake	WI	54517	USA
66	Great Lakes	Great Lakes	IL	60088	USA
67	New Orleans	New Orleans	LA	70146	USA
68	Tinker Afb	Tinker Afb	OK	73145	USA
69	Mcalester	Mcalester	OK	74501	USA
70	Hurst	Hurst	TX	76053	USA
71	Fort Worth	Fort Worth	TX	76127	USA
72	Lackland Afb	Lackland Afb	TX	78236	USA
73	Ingleside	Ingleside	TX	78362	USA
74	Kingsville	Kingsville	TX	78363	USA
75	Corpus Christi	Corpus Christi	TX	78419	USA
76	Yuma	Yuma	AZ	85369	USA
77	White Sands	White Sands	NM	88002	USA
78	Fallon	Fallon	NY	89496	USA
79	Seal Beach	Seal Beach	CA	90740	USA
80	Corona	Corona	CA	91718	USA
81	Fallbrook	Fallbrook	CA	92028	USA
82	Camp Pendleton	Camp Pendleton	CA	92055	USA
83	Subase San Diego	San Diego	CA	92106	USA
84	San Diego	San Diego	CA	92132	USA
85	North Island	San Diego	CA	92135	USA

	CONTINENTAL US				
	Demand Region	**City**	**State**	**ZIP Code**	**Country**
86	Navsta San Diego	San Diego	CA	92136	USA
87	Mirimar	San Diego	CA	92145	USA
88	El Centro	El Centro	CA	92243	USA
89	Santa Ana	Santa Ana	CA	92709	USA
90	Anaheim	Anaheim	CA	92803	USA
91	Point Mugu	Point Mugu	CA	93042	USA
92	Port Hueneme	Port Hueneme	CA	93043	USA
93	Lemoore	Lemoore	CA	93246	USA
94	Edwards Afb	Edwards Afb	CA	93523	USA
95	China Lake	China Lake	CA	93555	USA
96	Moffett Field	Moffett Field	CA	94035	USA
97	San Bruno	San Bruno	CA	94066	USA
98	Alameda	Alameda	CA	94501	USA
99	Stockton	Stockton	CA	95203	USA
100	Everett	Everett	WA	98201	USA
101	Oak Harbor	Oak Harbor	WA	98278	USA
102	Bremerton	Bremerton	WA	98314	USA
103	Silverdale	Silverdale	WA	98315	USA
		OVERSEAS			
1	Melbourne	Melbourne			AUS
2	Bahrain	Al Manamah			BHR
3	Kemps Bay	Kemps Bay			BHS
4	Guantanamo Bay	Guantanamo Bay			CUB
5	Diego Garcia	Diego Garcia			DGC
6	Rota	Rota			ESP
7	Glasgow	Glasgow			GBR
8	Soudha Bay	Soudha			GRC
9	Keflavik	Keflavik			ISR
10	Naples	Naples			ITA
11	Yokosuka	Yokosuka			JPN
12	Pusan	Pusan			KOR
13	Christchurch	Christchurch			NZL
14	Singapore	Singapore			SGP
15	Barbers Point	Barbers Point	HI	96862	USA
16	Camp H M Smith	Camp H M Smith	HI	96861	USA
17	Kekaha	Kekaha	HI	96752	USA
18	Pearl Harbor	Pearl Harbor	HI	96860	USA
19	Schofield Barracks	Schofield Barracks	HI	96857	USA
20	Wahiawa	Wahiawa	HI	96786	USA
21	Waianae	Waianae	HI	96792	USA
22	Guam	Santa Rita	GU	96910	USA
23	Puerto Rico	Ceiba	PR	00735	USA

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APPENDIX B. DEFENSE DEPOTS

	Defense Depot		Indoor Cap. (K cf)	Outdoor Cap. (K cf)	Depot Cost ($)	State	ZIP Code	Country
1	DDAG	Albany	17,091	882		GA	31704	USA
2	DDAA	Anniston	16,137	25,980		AL	36201	USA
3	DDBC	Barstow	12,241	16,974		CA	92311	USA
4	DDCN	Cherry Point	3,143	2,408		NC	28533	USA
5	DDCO	Columbus	12,771	0		OH	43216	USA
6	DDCT	Corpus Christi	1,806	1,230		TX	78419	USA
7	DDHU	Hill	16,721	0		UT	84056	USA
8	DDJF	Jacksonville	4,610	2,390		FL	32212	USA
9	DDMC	McClellan	7,380	2,340		CA	95652	USA
10	DDNV	Norfolk	17,937	1,898		VA	23512	USA
11	DDOU	Ogden	1,333	0		UT	84407	USA
12	DDOO	Oklahoma City	18,541	5,576		OK	73145	USA
13	DDPW	Puget Sound	2,101	380		WA	98314	USA
14	DDRT	Red River	27,702	11,466		TX	75507	USA
15	DDRV	Richmond	28,189	5,740		VA	23297	USA
16	DDJC	San Joaquin	53,420	4,569		CA	95376	USA
17	DDDC	San Diego	9,058	2,446		CA	92136	USA
18	DDSP	Susquehanna	59,337	13,193		PA	17055	USA
19	DDTP	Tobyhanna	13,202	8,280		PA	18466	USA
20	DDWG	Warner Robins	17,448	2,629		GA	31098	USA
21	DDPH	Pearl Harbor	5,071	819		HI	96860	USA
22	DDYJ	Yokosuka	4,733	436		JPN		JPN

Depot costs and cost functions are withheld by request of the sponsor, Naval inventory Control Point, Code 041, Mechanicsburg, PA.

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APPENDIX C. TRANSPORTATION MATRIX

MODES	SPEED	TIME	COST	RATES	CHARACTERISTICS/ RESTRICTIONS
Air Freight (United, TWA, American et al)	Very Fast	<12 hours	High	$58.44 (Pcs 0-50 lbs) $136.00 (Pcs 51-100 lbs)	**SIZE:** Physical Size- Aircraft dependant (e.g DC-9 door = 53" × 30") **WT:** Max Wt 330 lbs **SPEC:** Air restricted hazmat, no security cargo **ITV:** Good ITV **SERV:** No pick up or delivery services; Port to Port
Small Parcel (FedEx – GSA contract)	Fast	24 hours	Average	$.81/lbs	**SIZE:** 119" in length and width height not over 165" **WT:** 150Lbs or less **SPEC:** No special Handling (refer, hazmat) without additional charge **ITV:** Good ITV - GTN linked **SERV:** Door-to-Door, pick up arranged with FedEx
Small Parcel Expedited	Fast	24 hours	High	$150+ $.96 per lb	**SIZE:** Surcharge for shipments over 125"L, 88"W, 59"H **WT:** Only shipments > 70 lbs **SPEC:** Case by case; air restricted hazmat; surcharge for hazmat **ITV:** Good ITV - will be GTN linked in future **SERV:** Door to Door, surcharge for weekend pick up/delivery
Small Parcel Routine	Fast	24-48 hours	Average	$1.00 / lbs	**SIZE:** Surcharge for oversized, outsized shipments **WT:** Shipments over 150 lbs (Navy policy) **SPEC:** Surcharge for hazmat **ITV:** Good ITV - will be GTN linked in future **SERV:** Door to Door, surcharge for weekend delivery where avail

MODES	SPEED	TIME	COST	RATES	CHARACTERISTICS/ RESTRICTIONS
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APPENDIX D. CUSTOMER DEMANDS AT EACH DEPOT THAT MINIMIZES TRANSPORTATION AND DEPOT COSTS

	Depots (K lb Throughput)																					
Demand Regions	DDAA	DDAG	DDBC	DDCN	DDCO	DDCT	DDHU	DDJF	DDMC	DDNV	DDOU	DDOO	DDPW	DDRT	DDRV	DDJC	DDDC	DDSP	DDTP	DDWG	DDPH	DDYJ
Pittsfield, MA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Newport, RI	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Portsmouth, NH	0.0	0.0	0.0	1,1435	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brunswick, ME	0.0	0.0	0.0	517.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bath, ME	0.0	0.0	0.0	28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cutler, ME	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Winter Harbor, ME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Groton, CT	0.0	0.0	0.0	12.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.2	0.0	0.0	0.0
Colts Neck, NJ	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0
Moorestown, NJ	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0
Lakehurst, NJ	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.6	0.0	0.0	0.0	0.0
Newburgh, NY	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2	0.0	0.0	0.0	0.0
Mechanicsburg, PA	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	86.4	0.0	0.0	0.0	0.0
Philadelphia, PA	0.0	0.0	0.0	112.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,420	0.0	0.0	0.0	0.0
Washington, DC	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Indian Head, MD	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Patuxent River, MD	0.0	0.0	0.0	22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	638.8	0.0	0.0	0.0	0.0
Solomons, MD	0.0	0.0	0.0	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Fort Meade, MD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
Andrews Afb, MD	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	106.7	0.0	0.0	0.0	0.0
West Bethesda, MD	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0
Bethesda, MD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Thurmont, MD	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quantico, VA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arlington, VA	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	571.7	0.0	0.0	0.0	0.0
Dahlgren, VA	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0
Williamsburg, VA	0.0	0.0	0.0	294.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chesapeake, VA	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wallops Island, VA	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8	0.0	0.0	0.0	0.0
Suffolk, VA	0.0	0.0	0.0	96.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Virginia Beach, VA	0.0	0.0	0.0	1,618	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norfolk, VA	0.0	0.0	0.0	1,766	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Little Creek, VA	0.0	0.0	0.0	46.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Newport News, VA	0.0	0.0	0.0	74.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yorktown, VA	0.0	0.0	0.0	56.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Portsmouth, VA	0.0	0.0	0.0	604.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cherry Point, NC	0.0	0.0	0.0	806.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jacksonville, NC	0.0	0.0	0.0	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Demand Regions	Depots (K lb Throughput)																					
	DDAA	DDAG	DDBC	DDCN	DDCO	DDCT	DDHU	DDJF	DDMC	DDNV	DDOU	DDOO	DDPW	DDRT	DDRV	DDJC	DDDC	DDSP	DDTP	DDWG	DDPH	DDYJ
Charleston, SC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N. Charleston, SC	0.0	0.0	0.0	4.3	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Goose Creek, SC	0.0	0.0	0.0	2.7	0.0	0.0	0.0	77.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Beaufort, SC	0.0	0.0	0.0	0.1	0.0	0.0	0.0	29.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marietta, GA	0.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	150.6	0.0	0.0
Savannah, GA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kings Bay, GA	0.0	0.0	0.0	8.7	0.0	0.0	0.0	46.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orange Park, FL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
St Augustine, FL	0.0	0.0	0.0	0.1	0.0	0.0	0.0	133.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jacksonville, FL	0.0	0.0	0.0	58.6	0.0	0.0	0.0	2,267	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cecil Field, FL	0.0	0.0	0.0	183.2	0.0	0.0	0.0	1,032	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mayport, FL	0.0	0.0	0.0	10.6	0.0	0.0	0.0	467.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Panama City, FL	0.0	6.5	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pensacola, FL	0.0	0.0	0.0	233.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Milton, FL	0.0	1.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orlando, FL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cape Canaveral, FL	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Patrick Afb, FL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Key West, FL	0.0	0.0	0.0	103.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Macdill Afb, FL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Meridian, MS	370.8	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stennis Space Center, MS	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pascagoula, MS	0.0	0.0	0.0	72.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Indianapolis, IN	0.0	0.0	0.0	0.0	23.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crane, IN	0.0	0.0	0.0	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Republic, MI	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Clam Lake, WI	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Great Lakes, IL	0.0	0.0	0.0	20.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Orleans, LA	0.0	0.0	0.0	261.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tinker Afb, OK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mcalester, OK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hurst, TX	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fort Worth, TX	0.0	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	241.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lackland Afb, TX	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ingleside, TX	0.0	0.0	0.0	2.1	0.0	29.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kingsville, TX	0.0	0.0	0.0	0.5	0.0	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corpus Christi, TX	0.0	0.0	0.0	17.4	0.0	441.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yuma, AZ	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0
White Sands, NM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Depots (K lb Throughput)																				
Demand Regions	DDAA	DDAG	DDBC	DDCN	DDCO	DDCT	DDHU	DDJF	DDMC	DDNV	DDOU	DDOO	DDPW	DDRT	DDRV	DDJC	DDDC	DDSP	DDTP	DDWG	DDPH	DDYJ
Fallon, NY	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seal Beach, CA	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78.0	0.0	0.0	0.0	0.0	0.0
Corona, CA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
Fallbrook, CA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Camp Pendleton, CA	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subase San Diego, CA	0.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.4	0.0	0.0	0.0	0.0	0.0
San Diego, CA	0.0	0.0	196.8	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
North Island, CA	0.0	0.0	2,050	144.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navsta San Diego, CA	0.0	0.0	238.1	19.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miramar, CA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
El Centro, CA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0
Santa Ana, CA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Anaheim, CA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point Mugu, CA	0.0	0.0	0.0	14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	375.2	0.0	0.0	0.0	0.0	0.0
Port Hueneme, CA	0.0	0.0	14.7	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lemoore, CA	0.0	0.0	0.0	54.1	0.0	0.0	0.0	0.0	1,271	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Edwards Afb, CA	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1	0.0	0.0	0.0	0.0	0.0
China Lake, CA	0.0	0.0	176.8	12.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moffett Field, CA	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	46.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
San Bruno, CA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alameda, CA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stockton, CA	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Everett, WA	0.0	0.0	0.0	40.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oak Harbor, WA	0.0	0.0	0.0	23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,126	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seattle, WA	0.0	0.0	0.0	65.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,414	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Silverdale, WA	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melbourne, AUS	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bahrain, BHR	0.0	0.0	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Kemps Bay, BHS	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guantanamo B.	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diego Garcia	0.0	0.0	0.0	114.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3
Rota, ESP	0.0	0.0	0.0	215.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	7.4	0.0	0.0	0.0
Glasgow, GBR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Soudha, GRC	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Keflavik, ISR	0.0	0.0	0.0	62.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Naples, ITA	0.0	0.0	0.0	732.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	7.8	0.0	0.0	0.0
Yokosuka, JPN	0.0	0.0	0.0	10.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,488
Pusan, KOR	0.0	0.0	0.0	42.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Christ Church, NZL	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Depots (K lb Throughput)																					
Demand Regions	DDAA	DDAG	DDBC	DDCN	DDCO	DDCT	DDHU	DDJF	DDMC	DDNV	DDOU	DDOO	DDPW	DDRT	DDRV	DDJC	DDDC	DDSP	DDTP	DDWG	DDPH	DDYJ
Singapore, SGP	0.0	0.0	0.0	**17.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Puerto Rico, PR	0.0	0.0	0.0	**251.4**	0.0	0.0	0.0	**5.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kekaha, HI	0.0	0.0	0.0	**7.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wahiawa, HI	0.0	0.0	0.0	**0.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**3.1**	0.0
Waianae, HI	0.0	0.0	0.0	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**6.6**	0.0
Schofield Bar., HI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.7**	0.0
Pearl Harbor, HI	0.0	0.0	0.0	**14.4**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**719.5**	0.0
Camp H M Smith, HI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barbers Point, HI	0.0	0.0	0.0	**8.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**465.0**	0.0
Guam, GU	0.0	0.0	0.0	**70.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.1**

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